United States Patent

[11] 3,581,535

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[21] Appl. No. **744,120**
[22] Filed **July 11, 1968**
[45] Patented **June 1, 1971**

[73] Assignee **The Goodyear Tire & Rubber Company**
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[54] **METHOD AND APPARATUS FOR MAKING BLADES**
35 Claims, 35 Drawing Figs.

[52] **U.S. Cl.** **72/7,**
72/297, 72/298, 72/300, 72/307, 72/312, 72/319, 72/388, 72/421

[51] **Int. Cl.** **B21d 11/02,**
B21d 11/04, B21d 31/00, B21d 43/02, B21d 11/20, B21d 11/22

[50] **Field of Search** 29/33, 34, 39, 51, 565, 566; 72/7, 296, 297, 298, 300, 306, 307, 311, 312, 319, 321, 388, 404, 405, 417, 421, 422; 113/119

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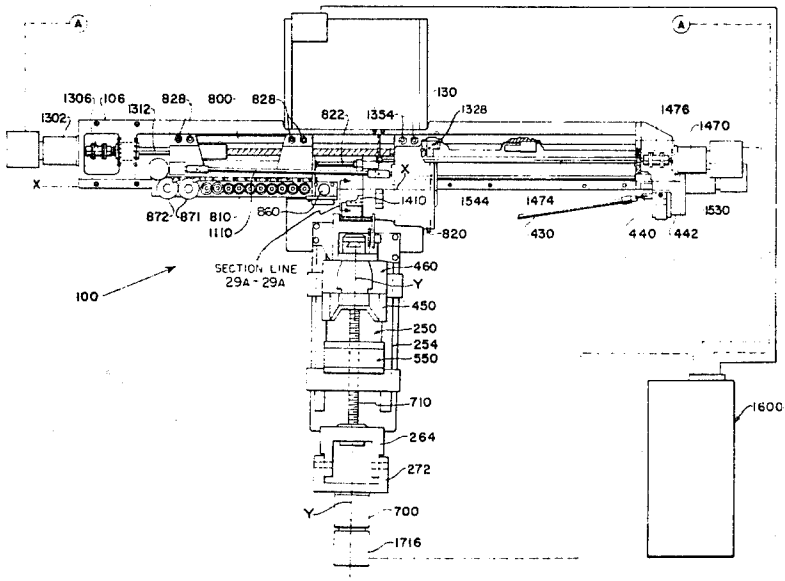
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Primary Examiner—Richard J. Herbst
Assistant Examiner—E. M. Combs
Attorneys—F. W. Brunner and R. S. Washburn

ABSTRACT: Method and apparatus for making blades for use in tire molds by piercing, notching, bending or otherwise altering shape of a free end of strip material by successively positioning the free end and a plurality of shape altering tools in operative engagement and cutting off a so-formed blade from the free end. Apparatus includes an automated machine tool having five axes of control and means for storing and for communicating command signals to each axis. Successive different blade configurations are made without revision of shaping tools. The strip, held by jaws, may be bent up or down in successive bends by a rotating bending device. A rotatable punch and die set is included.

The foregoing abstract is not to be taken as limiting the invention of this application, and in order to understand the full nature and extent of the technical disclosure of this application, reference must be made to the accompanying drawings and the following detailed description.



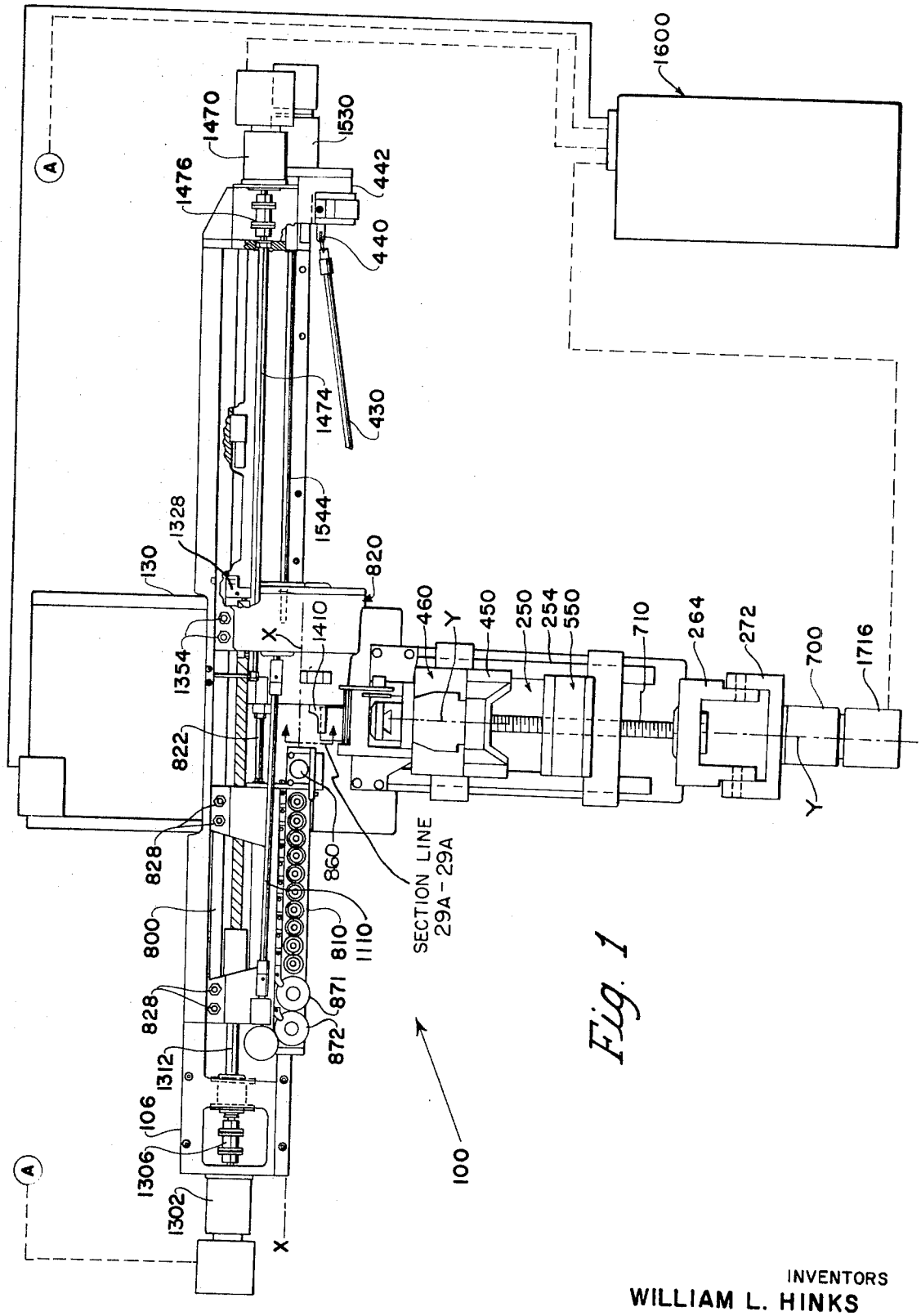


Fig. 1

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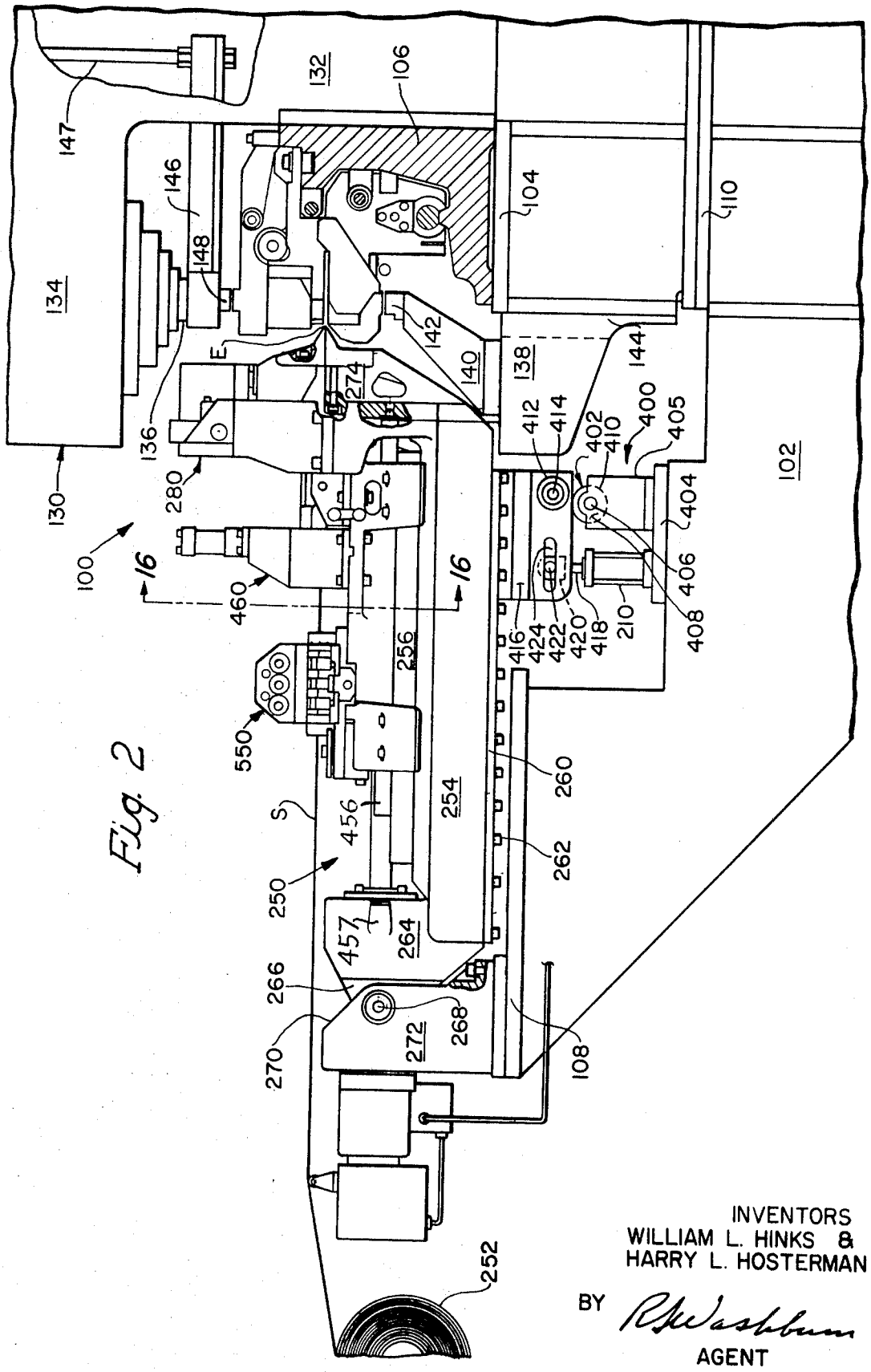


Fig. 2

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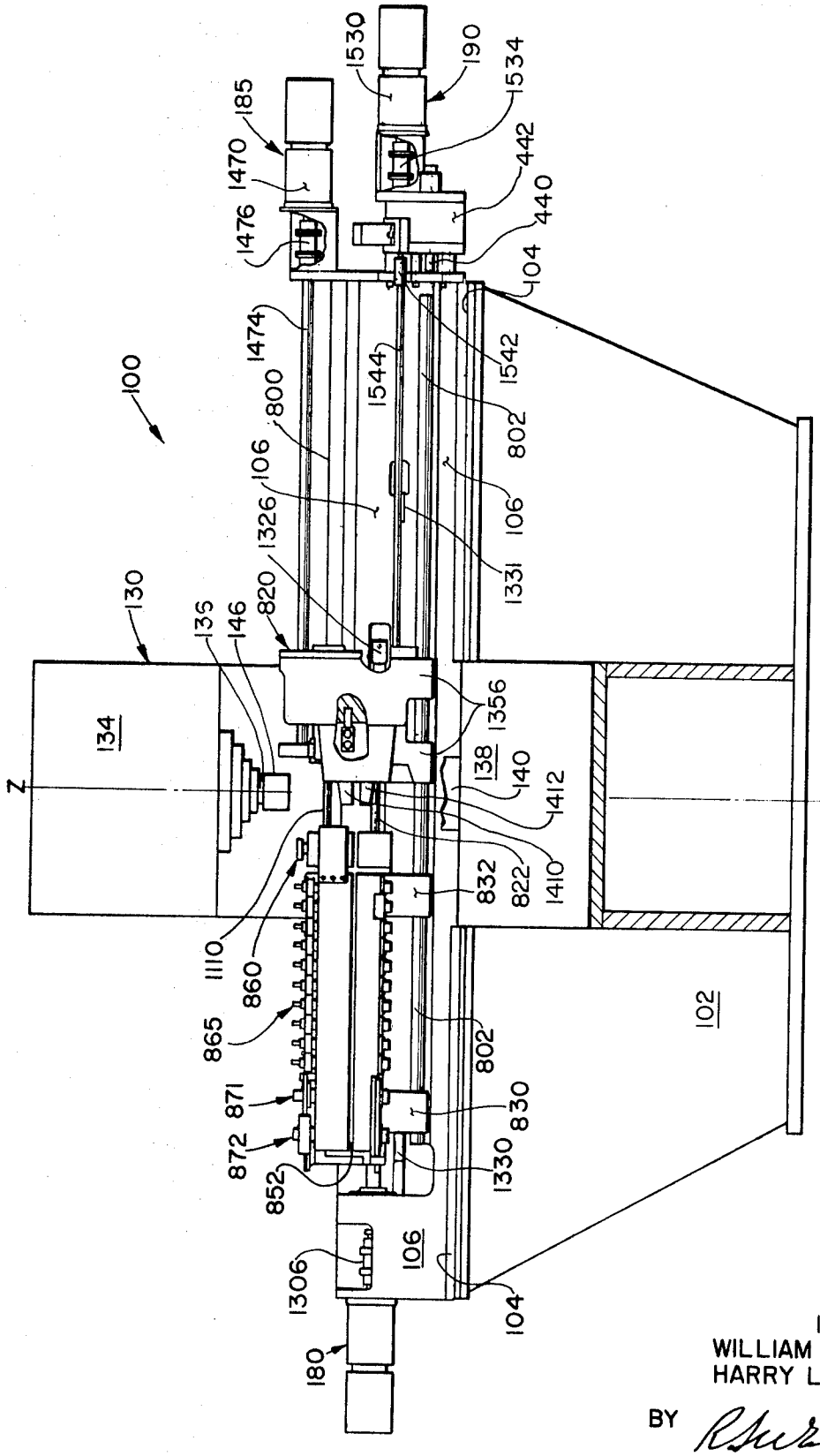


Fig. 3

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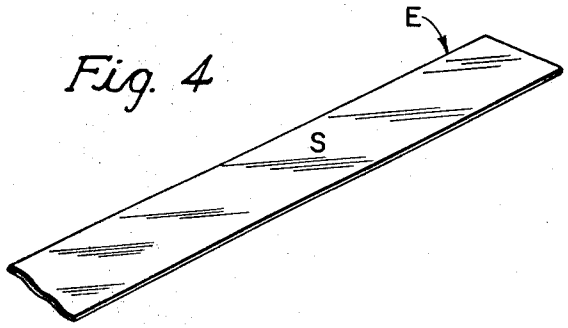


Fig. 4

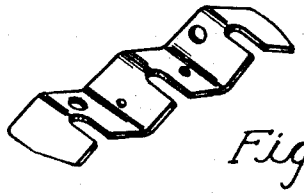


Fig. 7

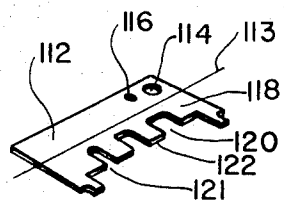


Fig. 5

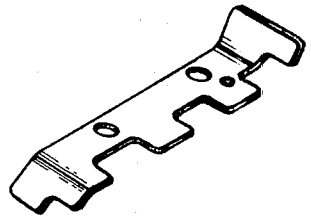


Fig. 8

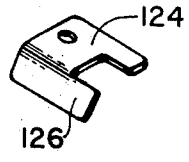


Fig. 6

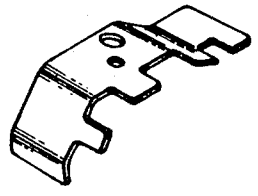


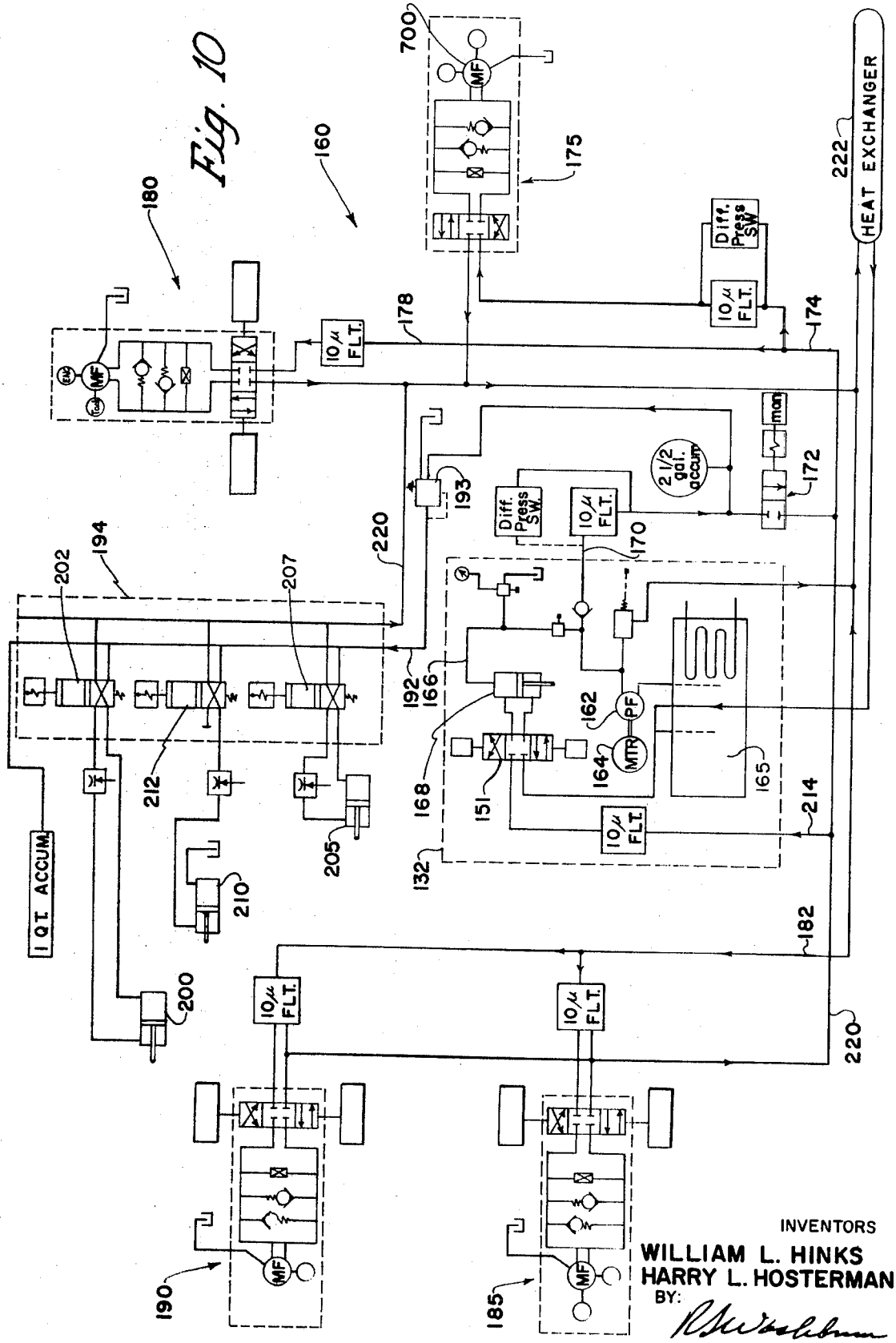
Fig. 9

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Fig. 10



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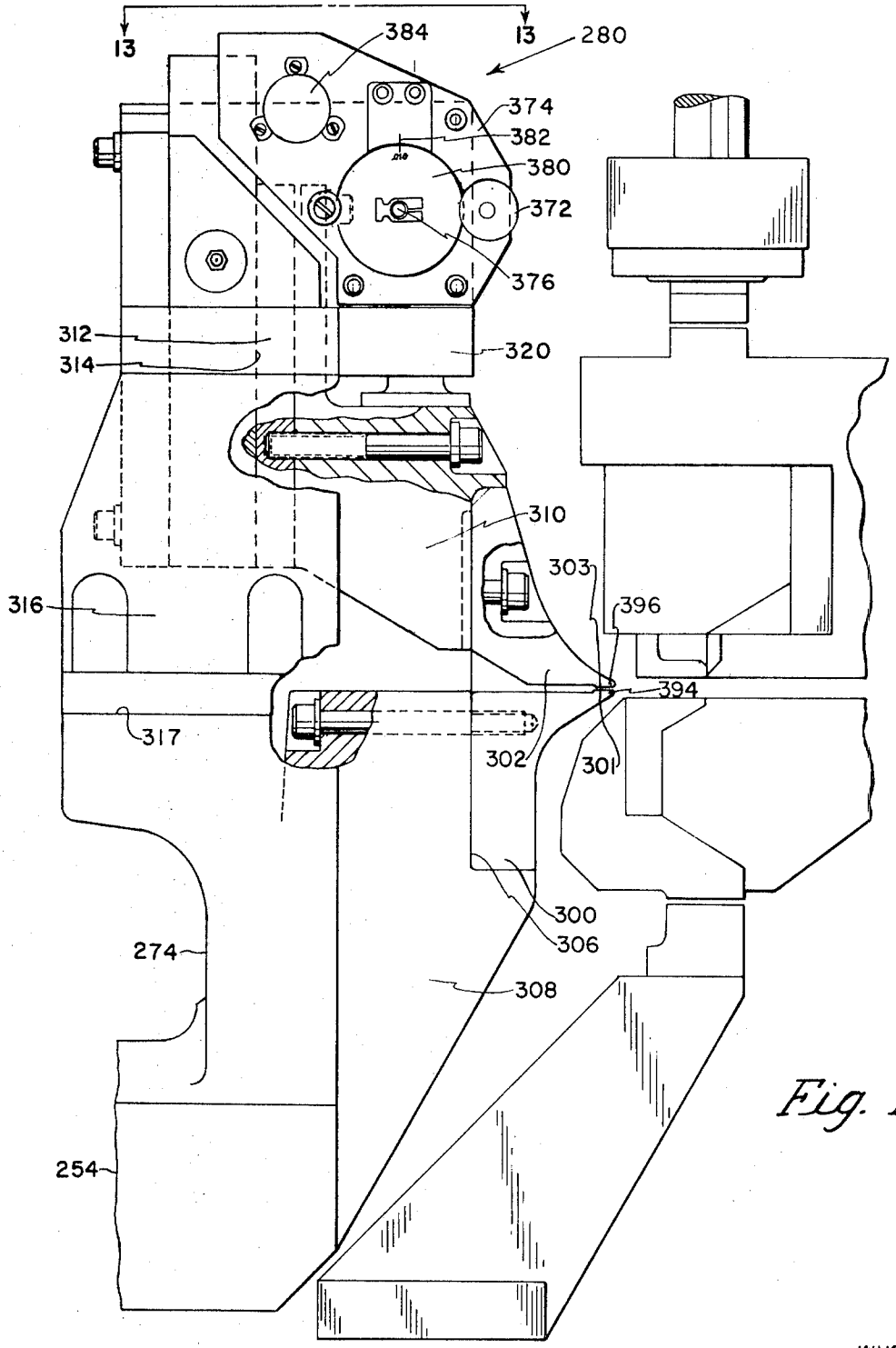


Fig. 11

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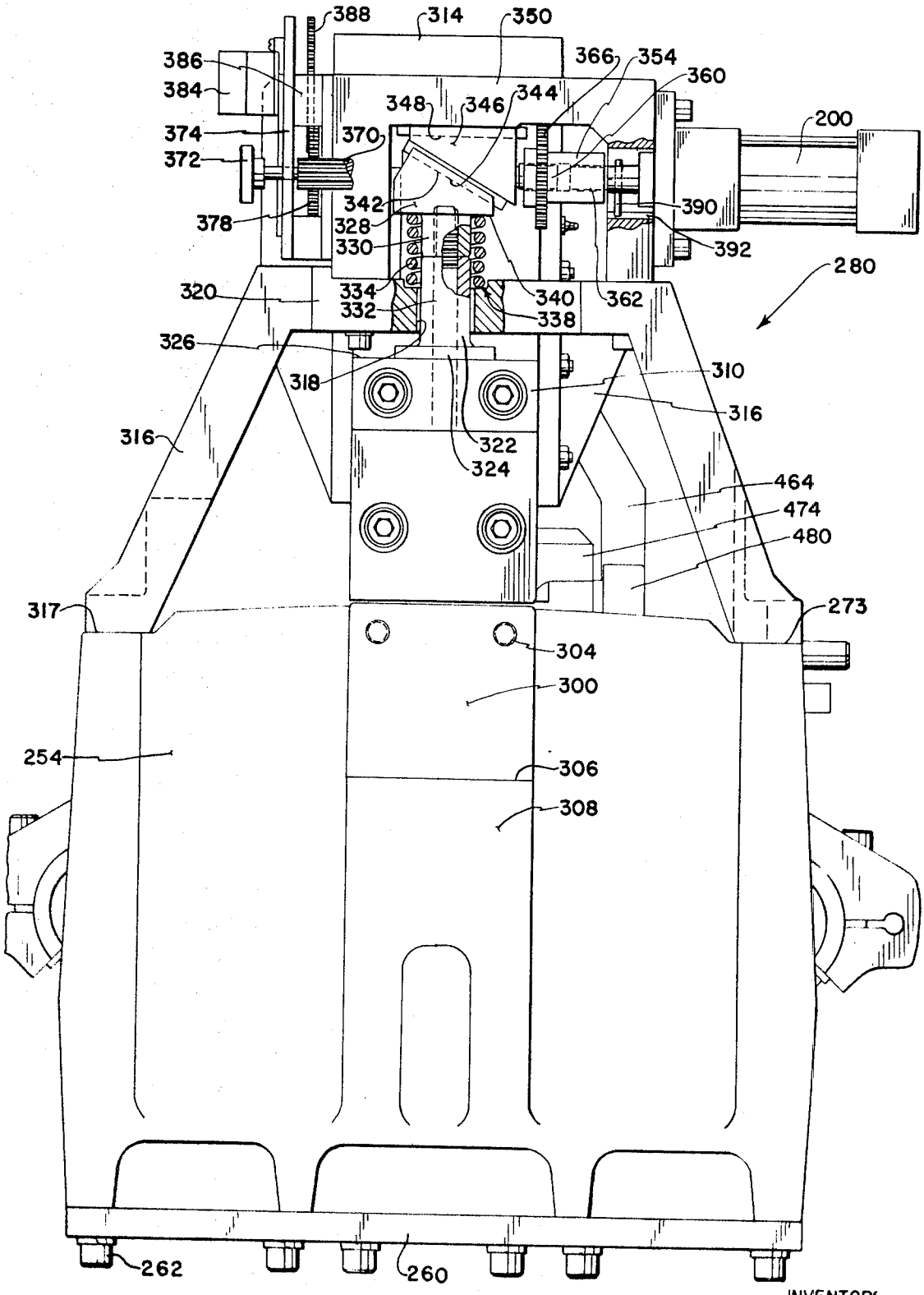


Fig. 12

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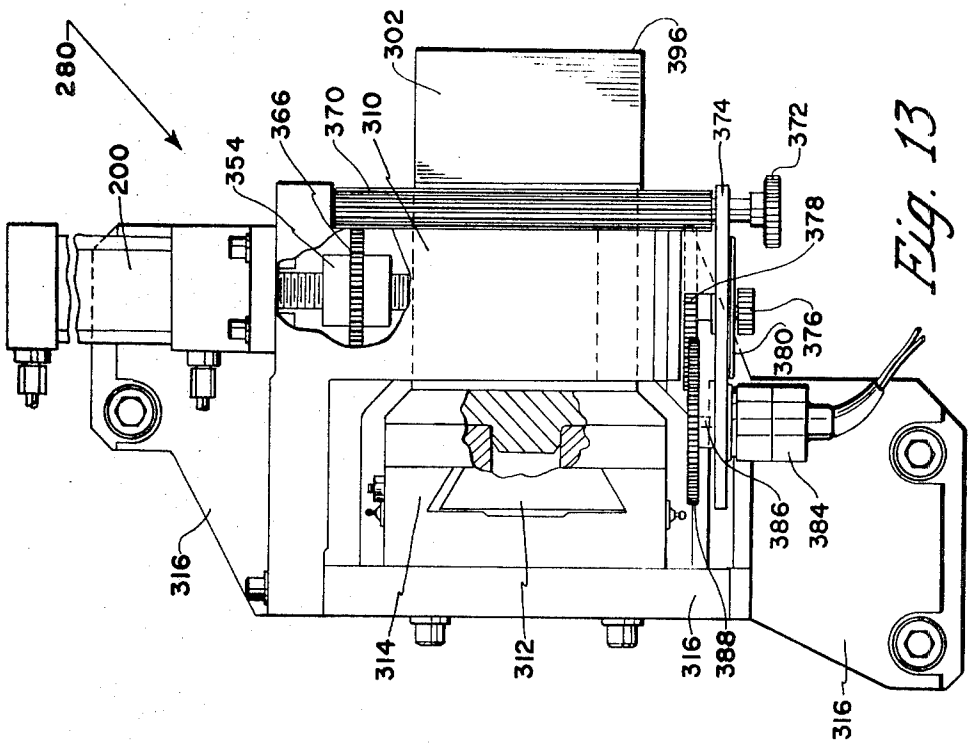


Fig. 13

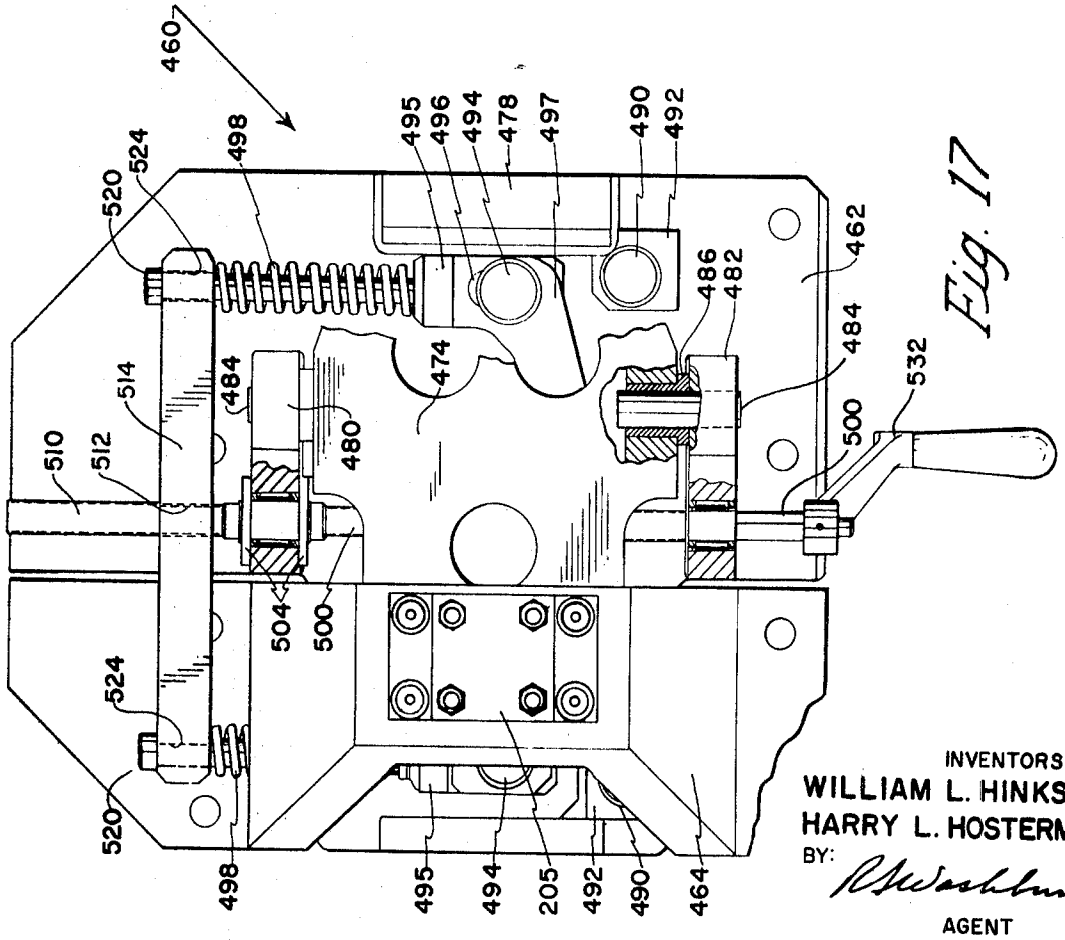


Fig. 17

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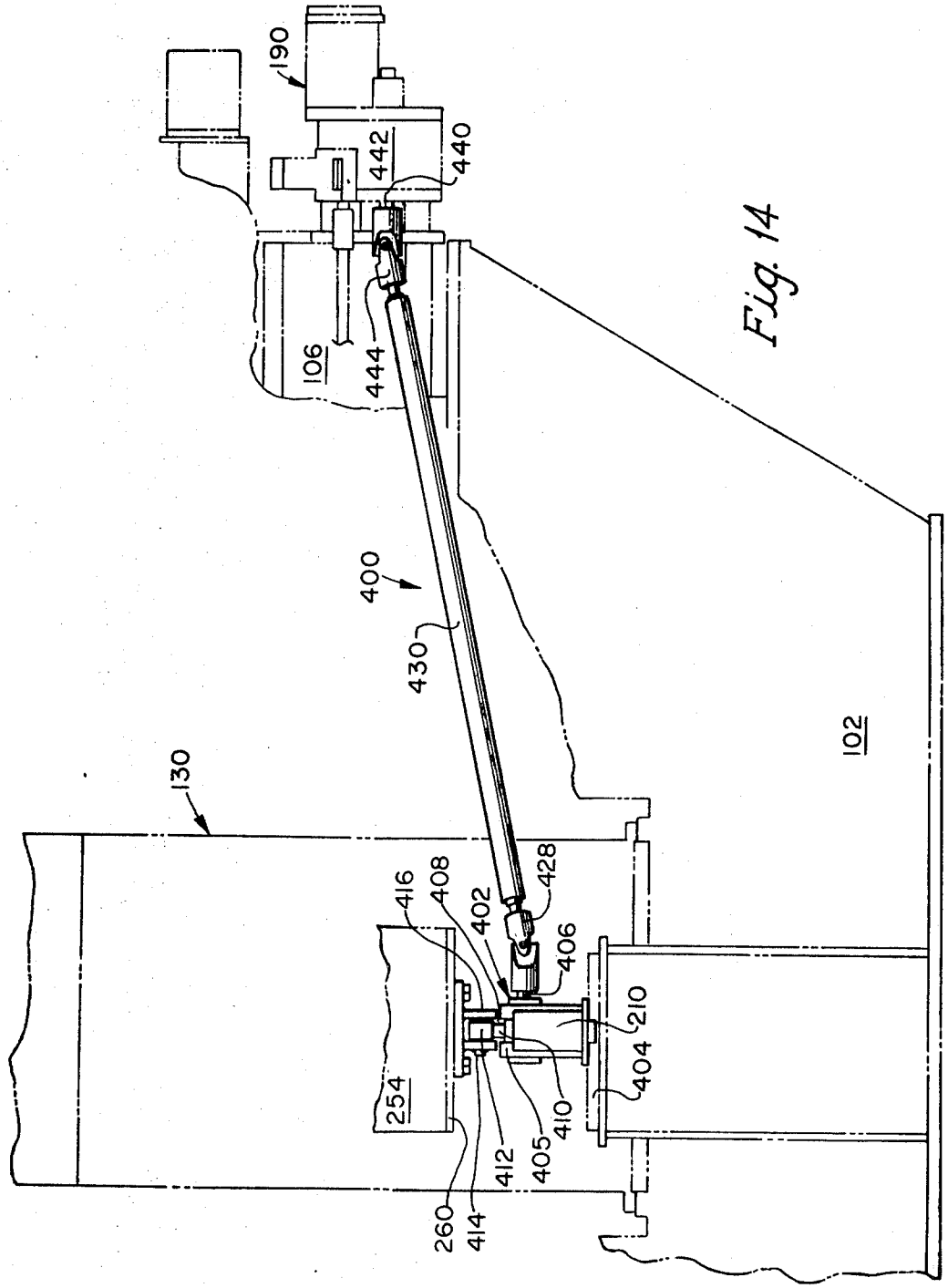


Fig. 14

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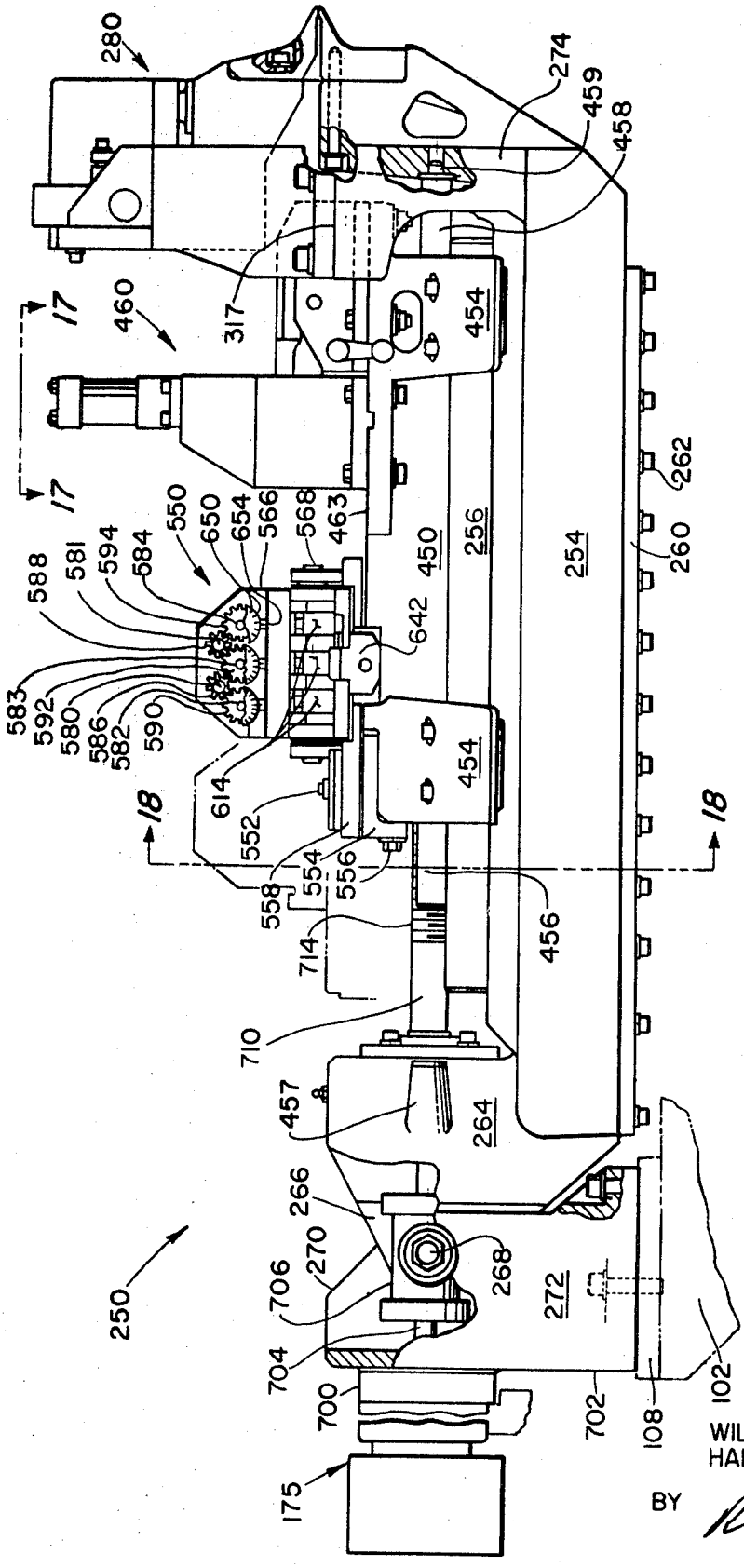
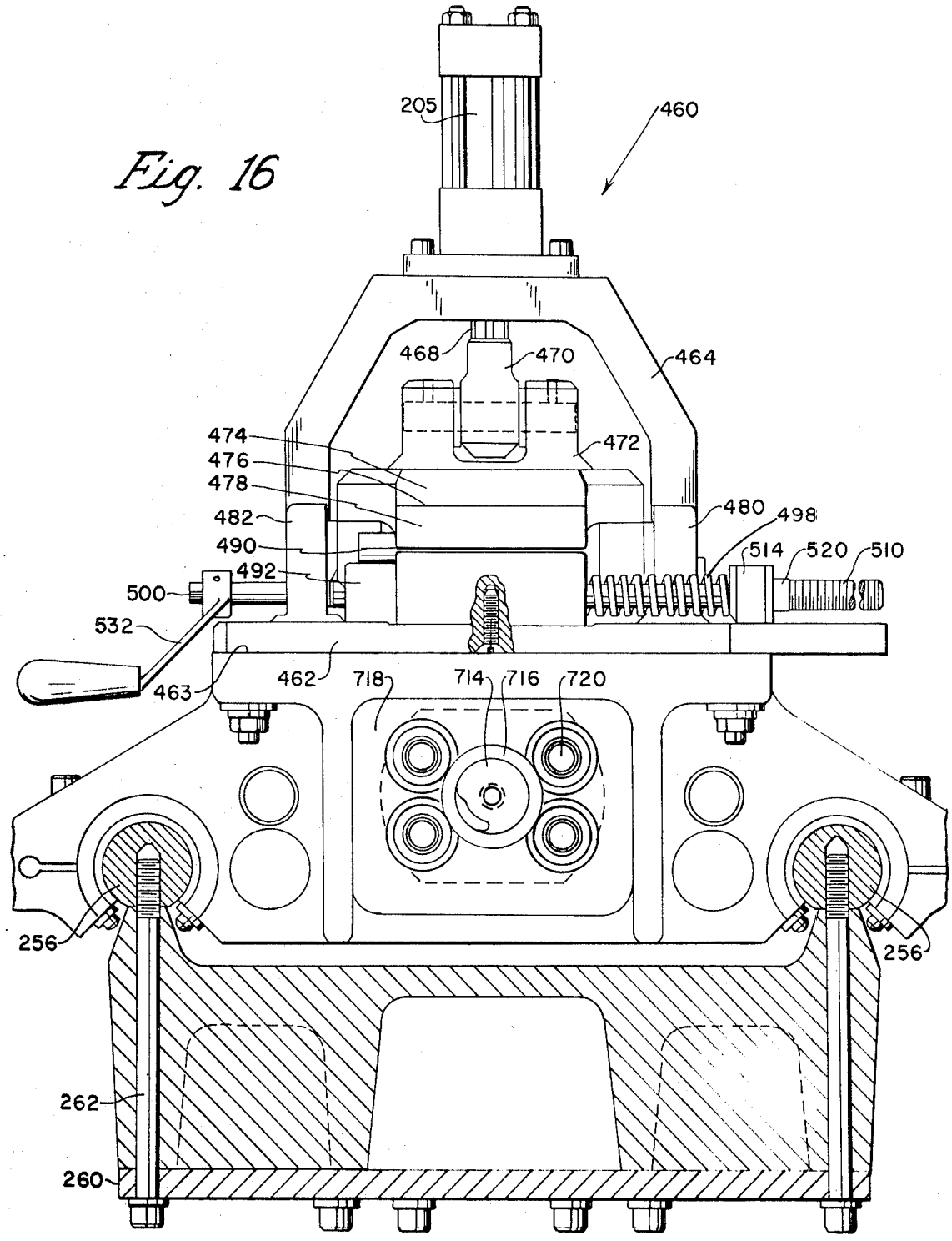


Fig. 15

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Fig. 16



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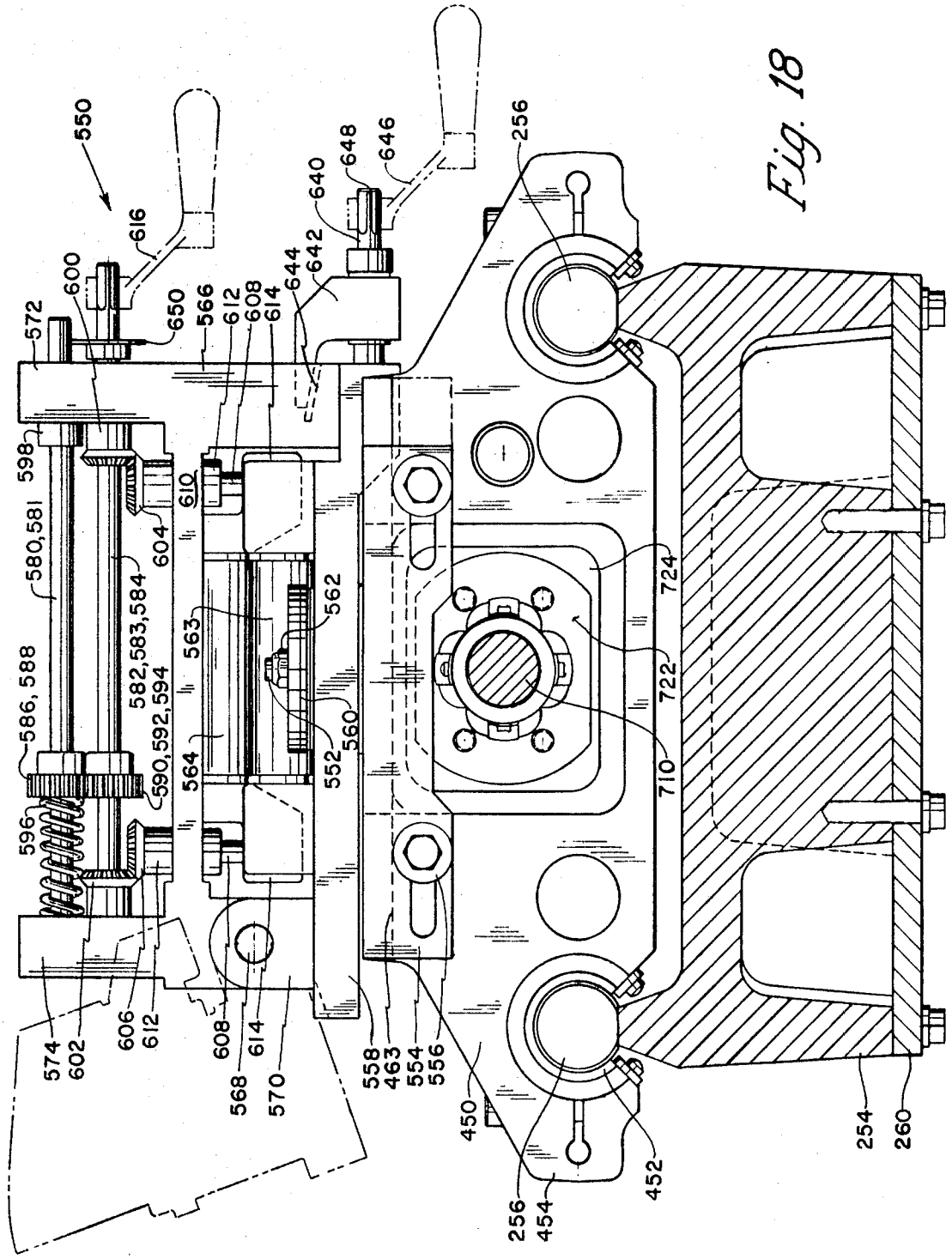


Fig. 18

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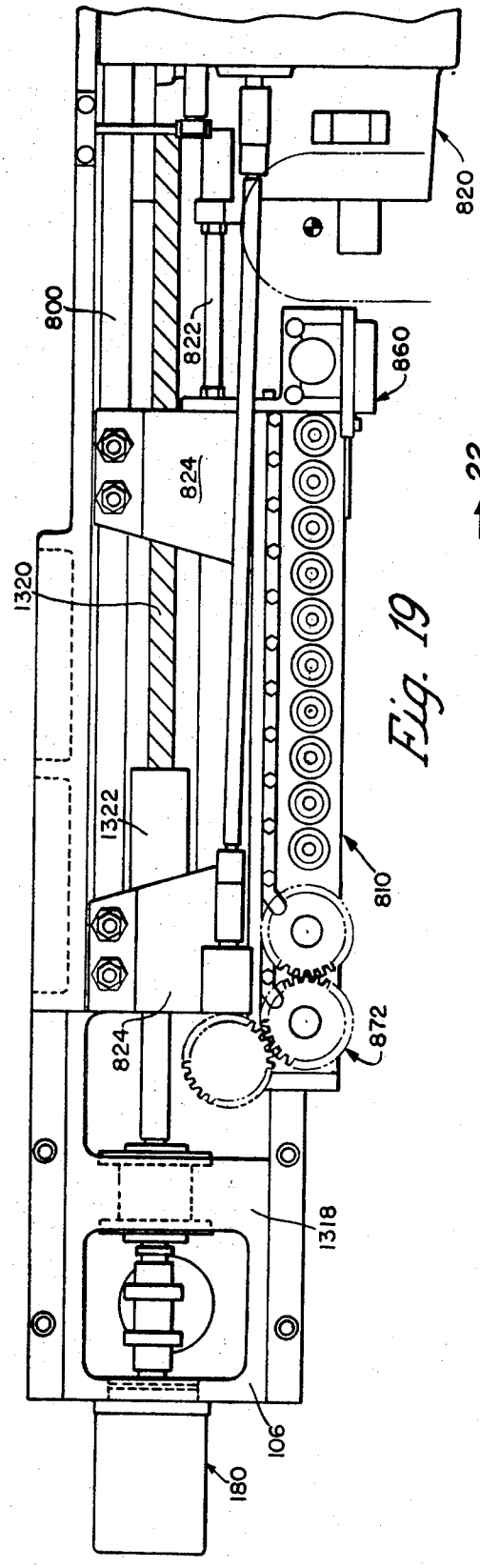


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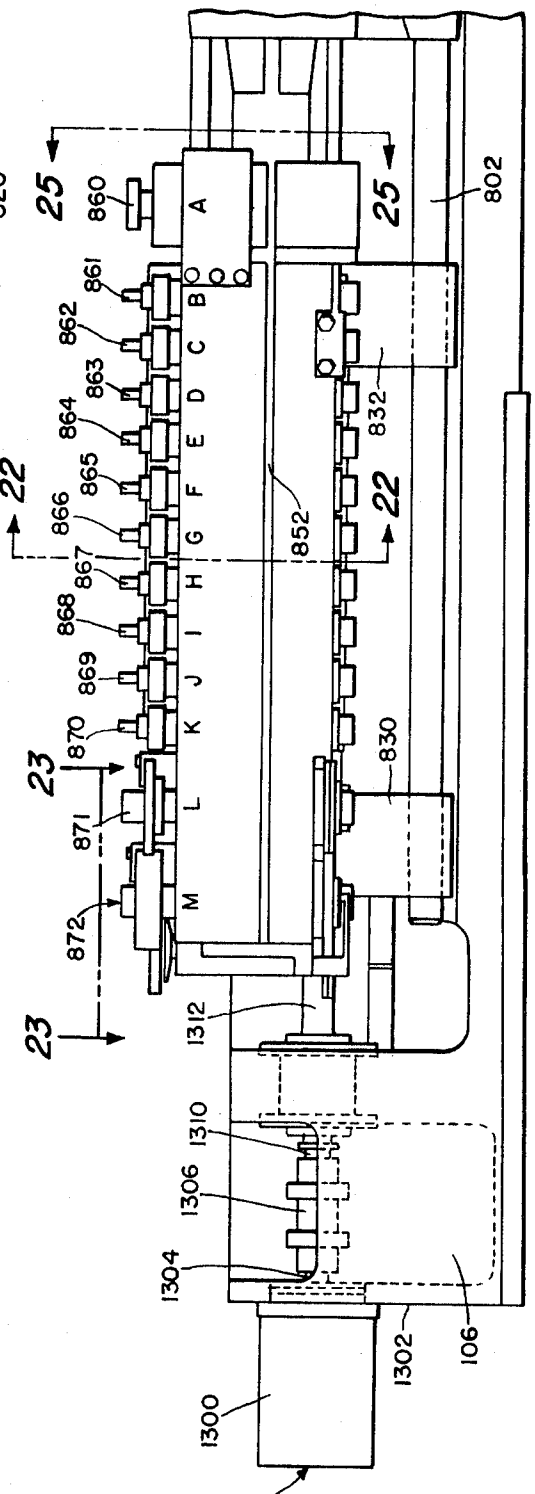


Fig. 20

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Fig. 36

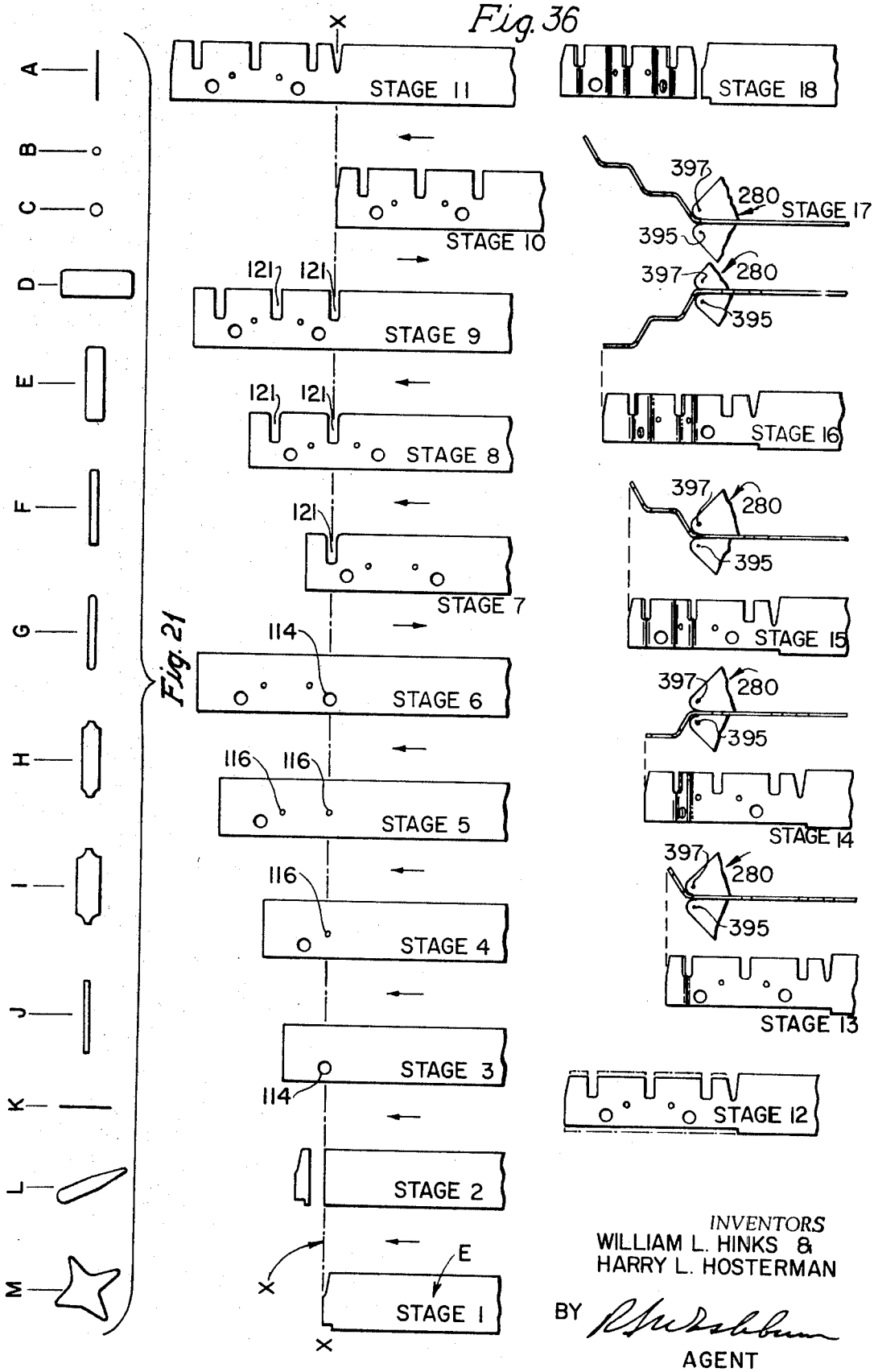


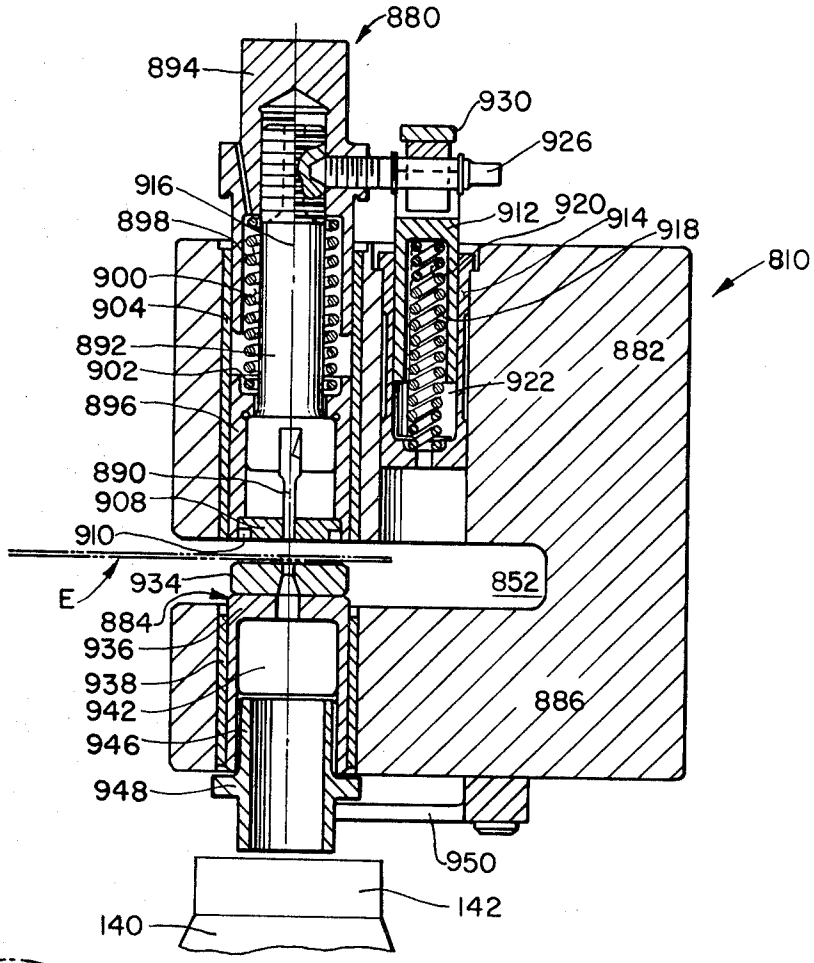
Fig. 21

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Fig. 22



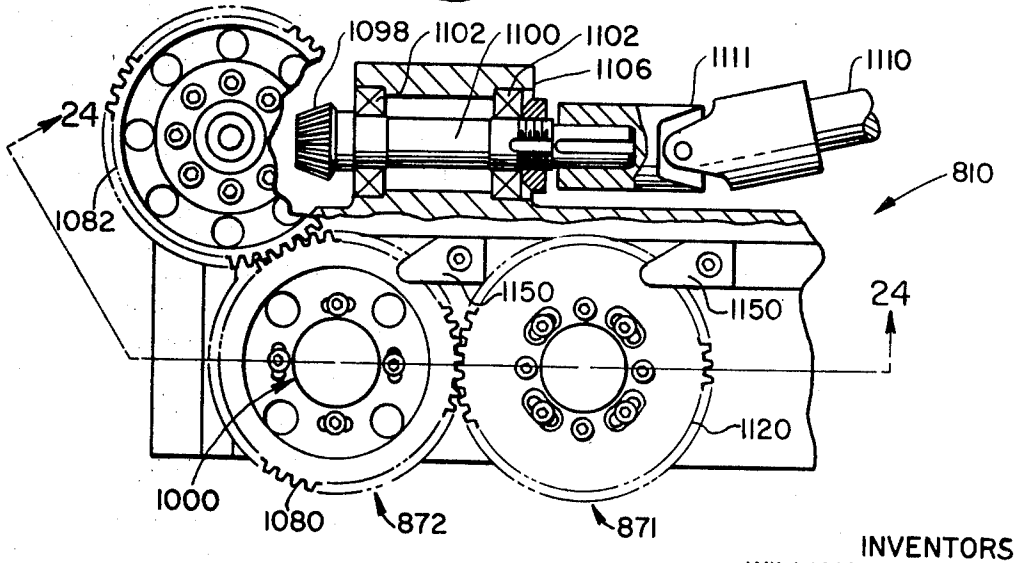


Fig. 23

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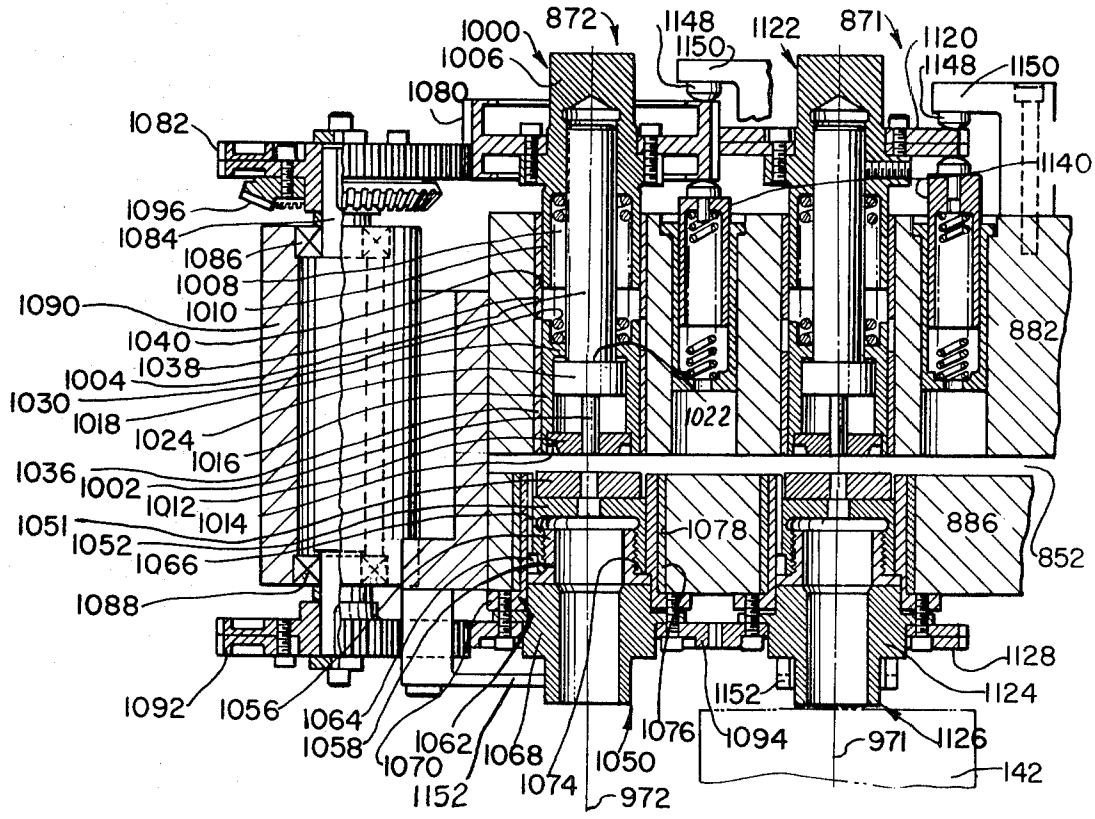


Fig. 24

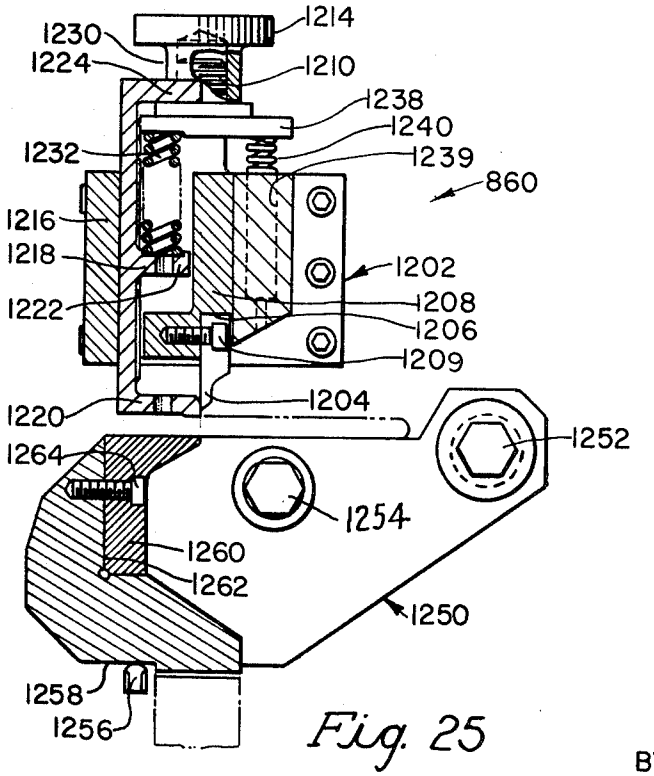


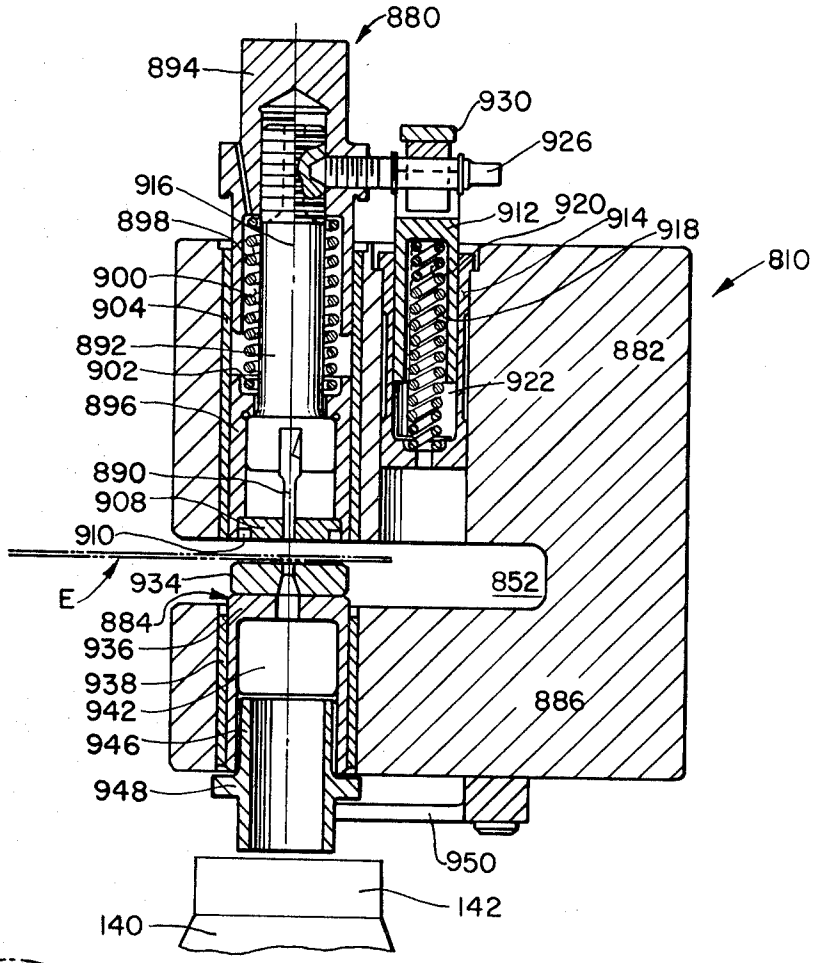
Fig. 25

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Fig. 22



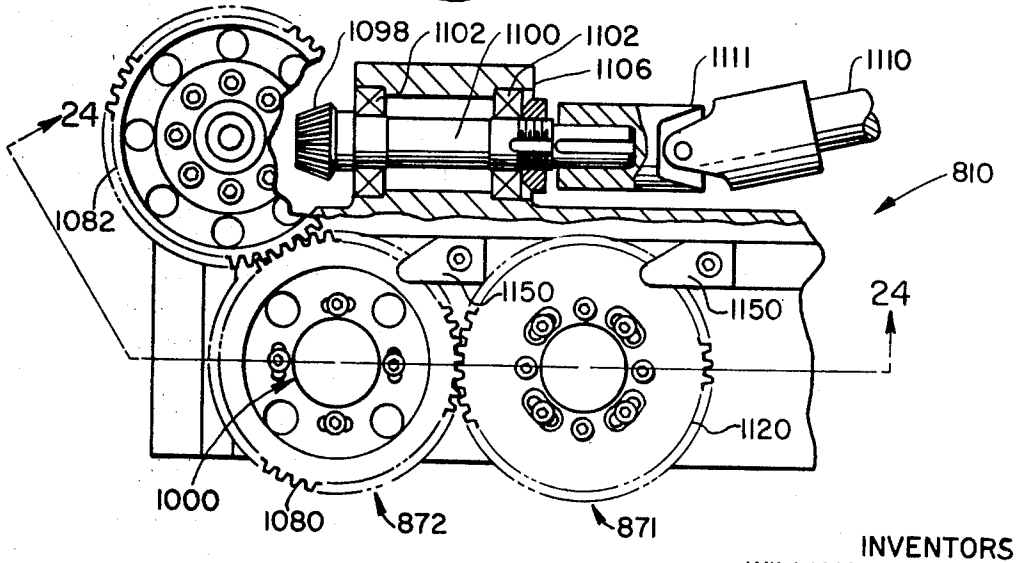


Fig. 23

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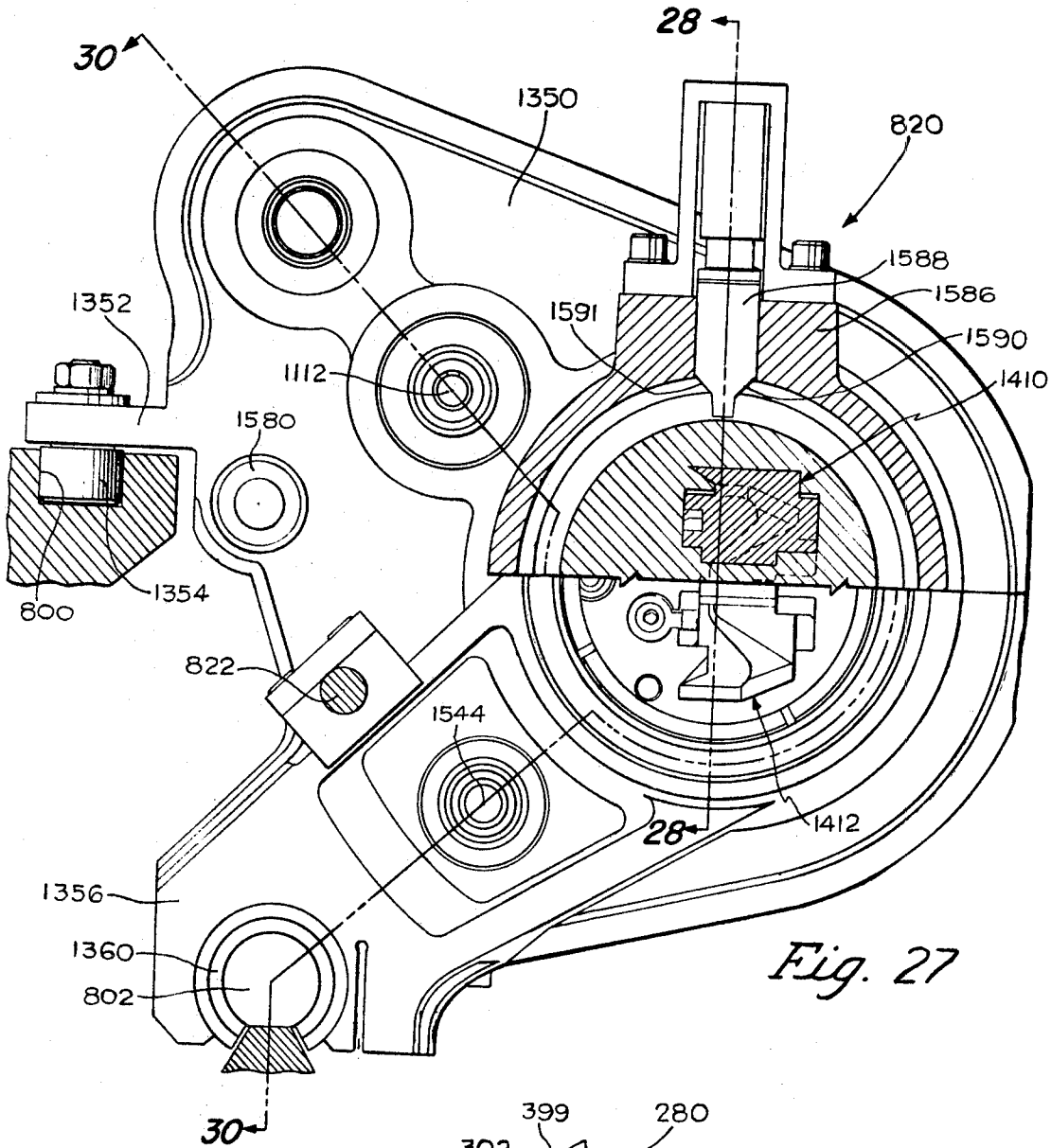


Fig. 27

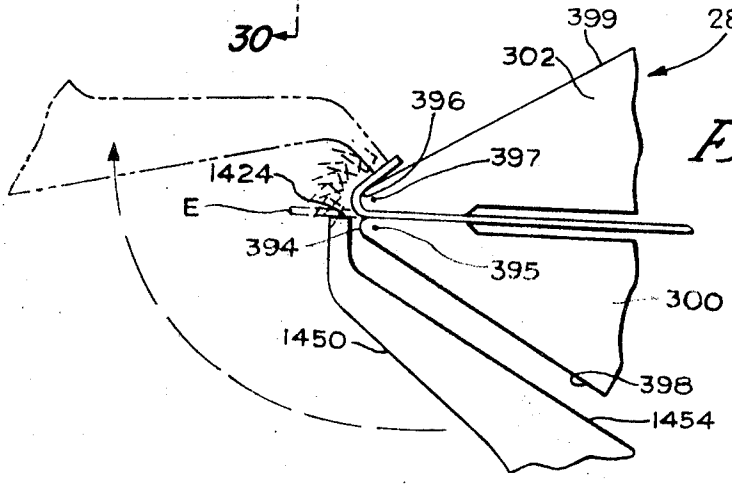


Fig. 29A

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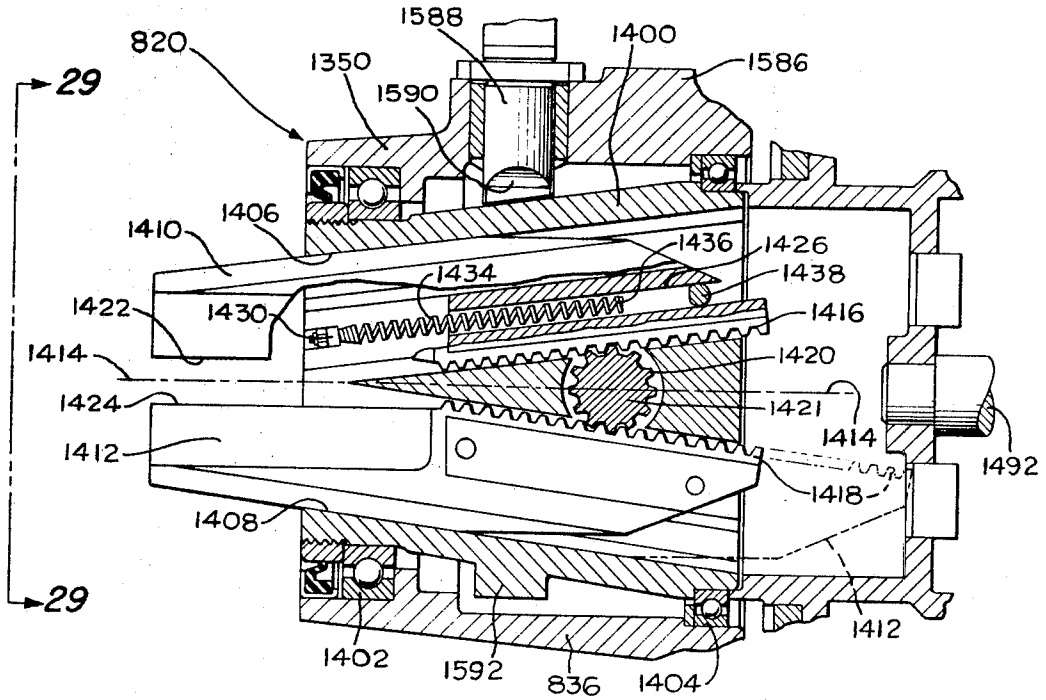


Fig. 28

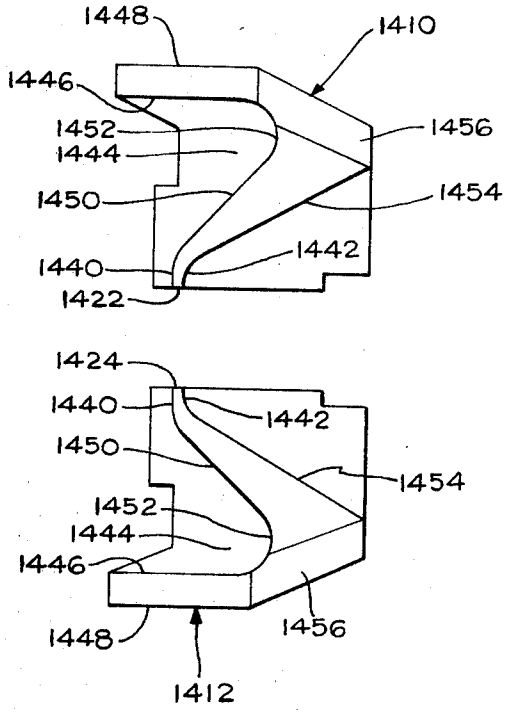


Fig. 29

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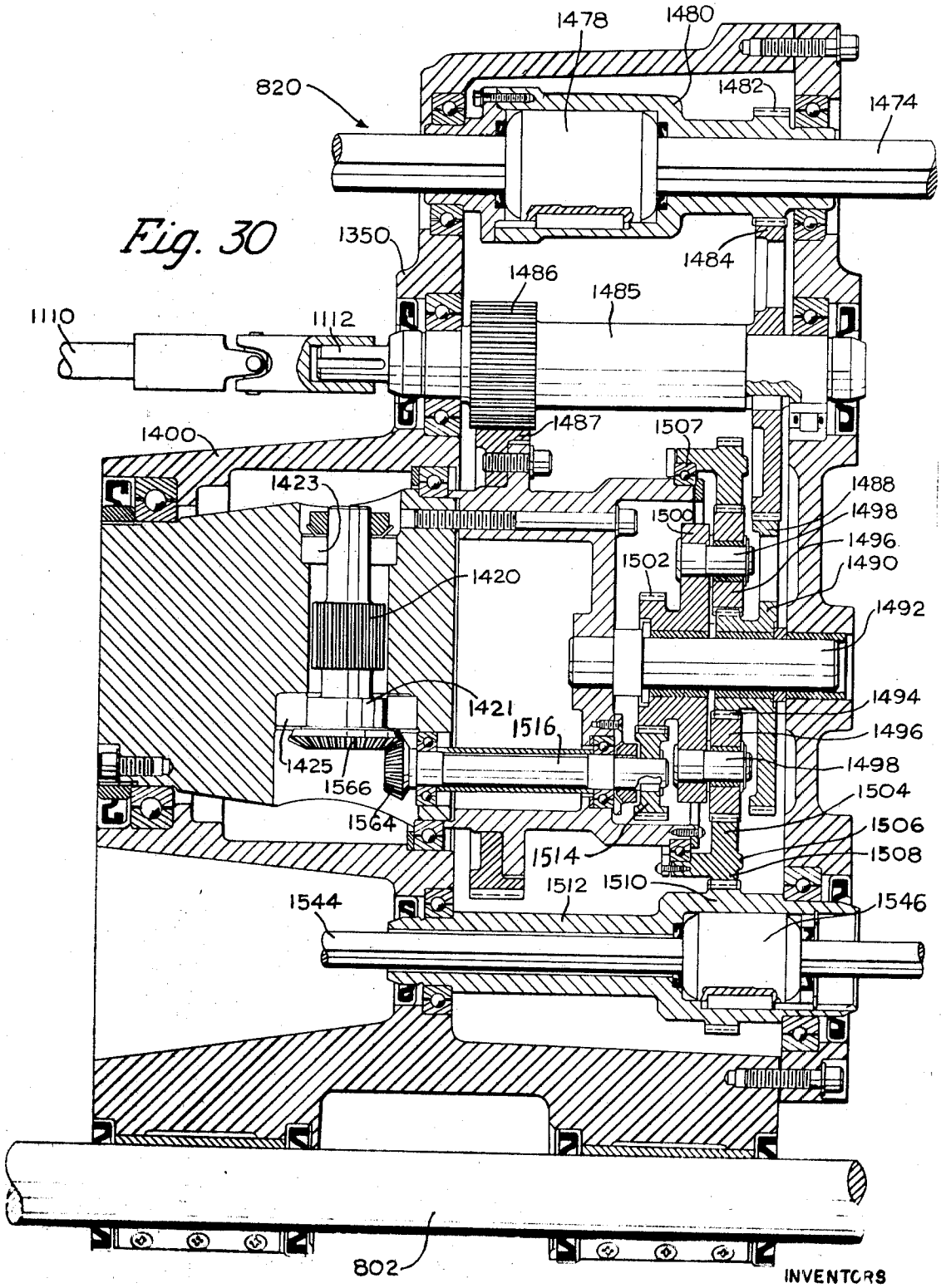


Fig. 30

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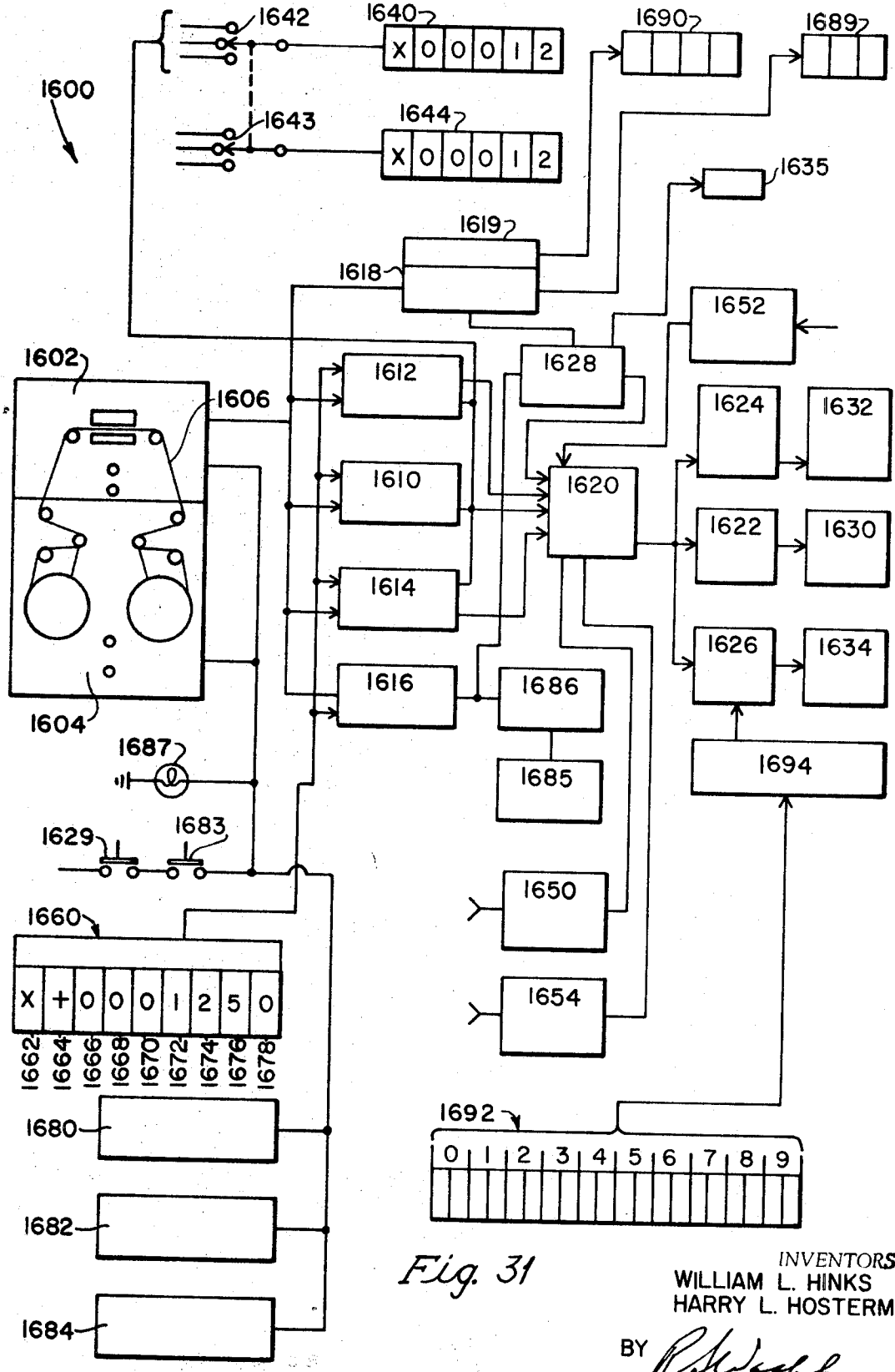


Fig. 31

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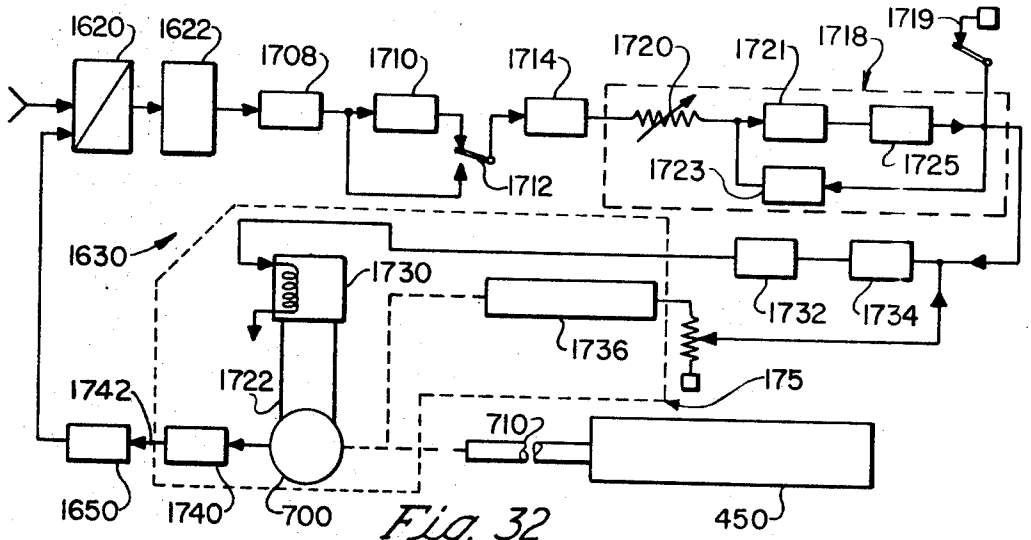


Fig. 32

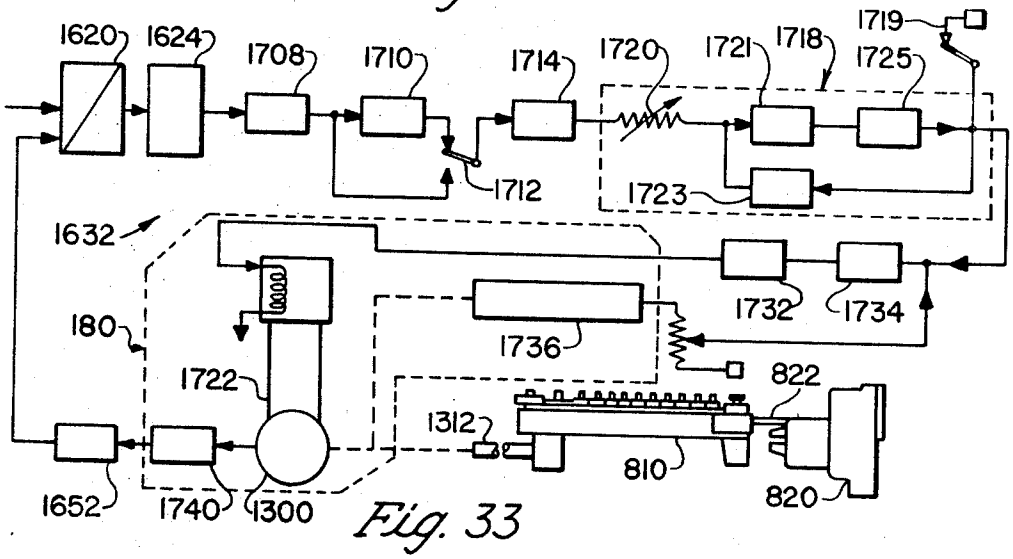


Fig. 33

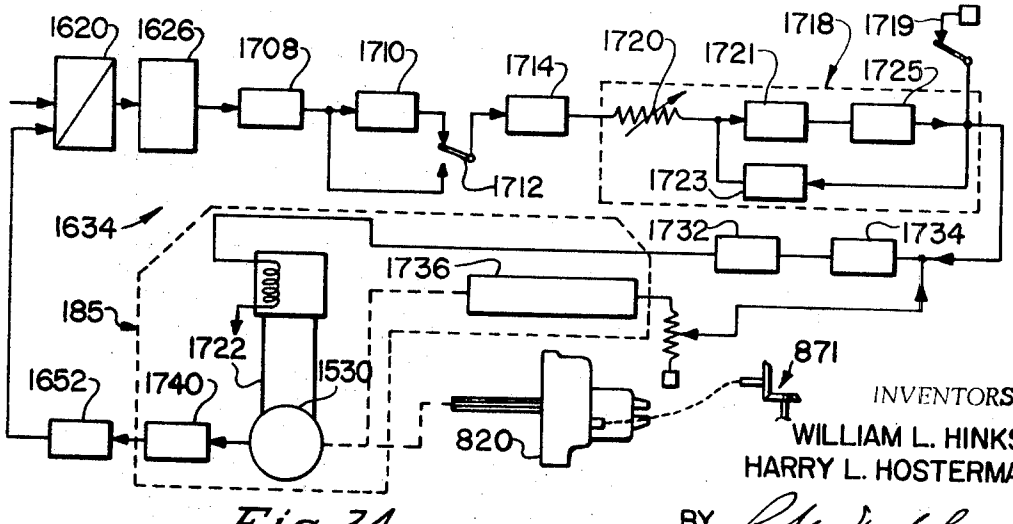


Fig. 34

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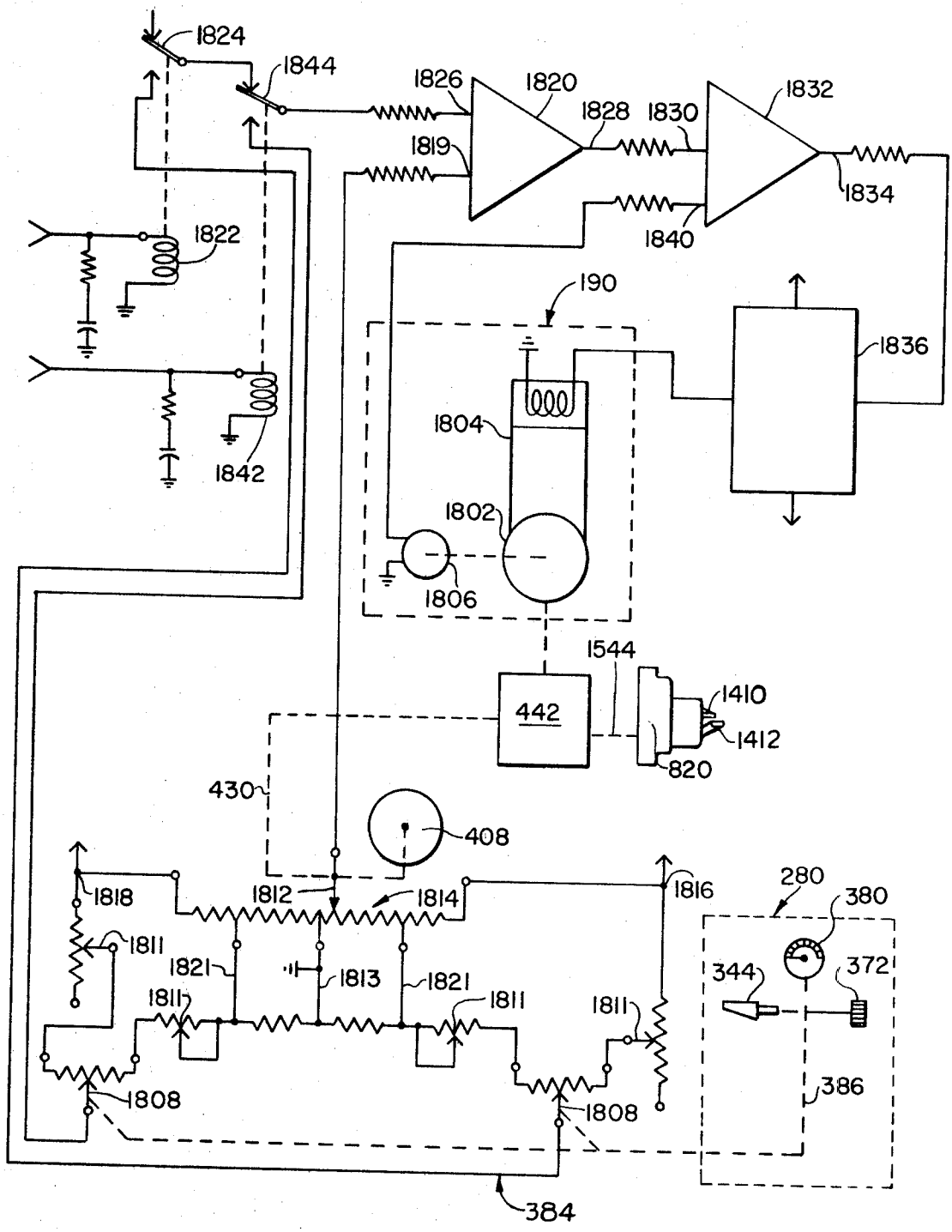


Fig. 35

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METHOD AND APPARATUS FOR MAKING BLADES

The present invention relates to making blades of the type which are inserted in tire molds to provide narrow grooves and similar impressions in the tread pattern of vehicle tires. MOre specifically, the invention relates to a method and an apparatus for manufacturing blades in a successive plurality of diverse shapes from an indefinite running length of strip stock.

Heretofore, blades for tire molds have been produced by stamping out the required shapes from sheet or strip material using generally conventional blanking, piercing, and forming dies, each of which is especially adapted to produce a single type and style of blade. A single tire mold for a particular tire employs a large number of blades and requires an average of 25 to 30 different blade configurations. It will be apparent that the procurement of specifically adapted blanking, piercing and bending die combinations required for each blade configuration is not only expensive but time consuming. Moreover, a large majority of tire designs processed in modern manufacture are experimental. Blades for more than a first mold may never be required so that relatively few blades of any particular configuration may be used. The cost per mold of blades made by conventional tools and methods is frequently excessive since any particular set of tools may be used to produce only a few blades.

Furthermore, the time required to prepare and put into use the conventional tooling to produce blades desired for an experimental tire mold may delay, and possibly prohibit, the testing of many desired experimental tire designs. The alternative of hand manufacture of the number of blades required for a single tire mold, although possible, is prohibitively expensive and still less satisfactory in terms of quality.

In addition to blades which are inserted or embedded in tire molds to mold forms conjugate to the blades themselves in a finished tire, blades suitable for use in electrical erosion machining of seats in which mold blades are subsequently embedded in tire molds, the process being known as "ELOX" machining, have been subject to the same disadvantages as have been cited. The present invention finds utility in both types of blades and in the present specification, both types as well as articles of similar character are referred to generically as blades.

It is therefore an object of the present invention to provide a technique or method capable of overcoming the difficulties and disadvantages of prior practice, and particularly to provide apparatus for carrying out the process so as to produce blades for tire molds at less cost and with less delay than heretofore required.

A further object of the instant invention is the provision of a system and apparatus capable of producing diverse shapes without the use of tools individually peculiar to the shapes of the blades required. An additional object is to provide a system and apparatus capable of blanking, piercing, or bending individual blades in immediately successive diverse configurations without requiring the procurement of tooling necessarily individually adapted to each of the desired configurations.

Still another object is the provision of apparatus for making blades of immediately successive different thicknesses, widths and materials without the necessity for any permanent modification or replacement of the tooling employed.

A further object of the present invention is the provision of apparatus for making blades, including immediately successive different blades, for tire molds, continuously and automatically from a running length of strip material, in predetermined number, character or sequence.

Other objects and advantages of the instant invention will become apparent or will be particularly pointed out in the description of specific aspects and particular embodiments of the invention which follows and from the annexed drawings forming a part of the description in which:

FIG. **1** is a plan view of apparatus embodying the invention;

FIGS. **2** and **3** are elevation views of the apparatus of FIG. **1** with portions broken away;

FIG. **4** is a perspective view of strip material useful in the practice of the invention;

FIGS. **5** through **9** are perspective views of blades made by practice of the invention;

FIG. **10** is a schematic diagram of the hydraulic system of the apparatus of FIG. **1**;

FIGS. **11** and **12** are elevation views of a portion of the Y axis component of the apparatus of FIG. **1**;

FIG. **13** is a plan view of a portion of the Y axis component of the apparatus of FIG. **1** taken as indicated by the line **13–13** in FIG. **11**;

FIG. **14** is an elevation view of elevator means included in the apparatus of FIG. **1**;

FIG. **15** is an elevation view of another portion of the Y axis component of the apparatus of FIG. **1**;

FIG. **16** is an elevation view of the carriage portion of the Y axis component of the apparatus of FIG. **1**, taken as indicated by the line **16–16** of FIG. **2**;

FIG. **17** is a plan view of the portion of the apparatus indicated by the line **17–17** of FIG. **15**;

FIG. **18** is an elevation view of the straightening device portion of the apparatus of FIG. **1**, taken as indicated by the line **18–18** of FIG. **15**;

FIG. **19** is a plan view and **20** is an elevation view of a portion of the X axis component of the apparatus of FIG. **1**, showing the tool carrier;

FIG. **21** is a diagram showing the configuration of punch and die sets useful in the apparatus of FIG. **1**;

FIG. **22** is a sectional view of a representative one of the punch and die sets included in the apparatus of FIG. **1**, taken as indicated by the line **22–22** of FIG. **20**;

FIG. **23** is a plan view of rotatable punch and die set portion of the apparatus of FIG. **1**, taken as indicated by the line **23–23** of FIG. **20**;

FIG. **24** is a sectional view, portions thereof broken away, of the rotatable punch and die sets taken as generally indicated by the line **24–24** of FIG. **23**;

FIG. **25** is a sectional view of the cutting-off device of the apparatus of FIG. **1**, taken as indicated by the line **25–25** of FIG. **20**;

FIG. **26** is an elevation view of another portion of the X axis component of the apparatus of FIG. **1**, showing the bending device;

FIG. **27** is an elevation view of the bending device taken as indicated by the line **27–27** of FIG. **26**;

FIG. **28** is a section view of the bending device taken as indicated by the line **28–28** of FIG. **27**;

FIG. **29** is an elevation view of the bending fingers, taken as indicated by the line **29–29** of FIG. **28**;

FIG. **29A** is a partial elevation view of the bending device of the apparatus of FIG. **1**, taken on the line **29A–29A** in FIG. **1**;

FIG. **30** is another sectional view of the bending device, taken as indicated by the line **30–30** of FIG. **27**;

FIG. **31** is a schematic diagram of means for storing and communicating signals, according to the invention;

FIG. **32** is a schematic diagram of the control system for the Y axis component of the apparatus of FIG. **1**;

FIG. **33** is a schematic diagram of the control system for the X axis component of the apparatus of FIG. **1**;

FIG. **34** is a schematic diagram of the control system for the *a* axis component of the apparatus of FIG. **1**;

FIG. **35** is a schematic diagram of the control system for the finger and jaw means of the apparatus of FIG. : and

FIG. **36** is a sequence diagram of successive operations to produce a blade by the method and apparatus of the invention.

According to the instant invention a method for making blades of divers configurations for use in molds for making tires comprises gripping a portion of a running length of a strip material so as to support cantileverly a free end of the strip and so as to make the free end suitable accessible to perform thereon a sequence of material removing altering and bending operations, moving the free end to successive predetermined

positions along an axis parallel to the running length of the strip, moving a plurality of tools individually and successively into a predetermined sequence of shape altering engagements with said free end so that at each of the said positions a portion of the free end is punched, trimmed, sheared, or bent and each shape altering engagement provides an increment of the total alteration desired to convert the strip material to a particular blade configuration.

A first completed blade is cut off from the free end thereby providing a second or new free end on the strip material. The second free end is immediately moved along the same axis to position the second free end successively to a second series of predetermined locations, which can be identical to the first series or differ therefrom, and the said tools are individually and successively moved into a second predetermined sequence of shape altering engagements with the second free end so that the second sequence is either identical to or different from the first sequence. In the former case, a second blade identical in configuration to the first is completed and cut off. In the latter sequence a second blade of different configuration follows immediately after the first blade. Successive repetitions of the steps yield successive identical blades or successive blades of great diversity without requiring the intermediate procurement or installation of specialized dies configured to suit the several diverse blade configurations.

THE APPARATUS IN GENERAL

According to the invention, apparatus particularly adapted for the practice of the method described is shown in the drawings. As in FIGS. **1**, **2** and **3**, the preferred apparatus takes the form of an automated machine tool **100** arranged to have three orthogonal axes indicated in the drawings by X, Y and Z. Principal operative movements of the X, Y, and Z components of the machine tool **100** take place in directions parallel to these axes respectively and the description of the apparatus makes reference to these axes for convenience and clarity. An *a* axis and a further special axis of operation and control will also be described.

Firstly, there will be described press means for actuating, individually, tools positioned in predetermined juxtaposed relation with a free end of a running length of strip material, which means is herein called the Z axis component and comprises in the present embodiment a punch press with certain appurtenances and modifications. Next will be described the means for positioning strip material and a free end thereof which in the present embodiment is termed the Y axis component and comprises strip material supply means, a strip moving carriage including straightening and guiding devices, gripping means for holding the strip, and elevation adjusting means. Thirdly, means for positioning tools individually into predetermined proximate relation to the free end of the strip material will be described, being referred to in the present embodiment and description as the X axis component and here comprising a tool positioning carrier movable along guide means and including a plurality of punch and die sets, a number of which may be rotatable, a cutoff die set, and a bending system and device. Finally, the system or means for storing and communicating to the several components of the machine tool a predetermined sequence or program of command signals will be described, which means in the present embodiment takes the form of a numerical control unit, operatively connected servocontrol circuits, and drive means responsive individually to the servocontrol circuits for providing movement respectively of the several components.

The machine tool **100** includes a base **102** suitably adapted to support and to maintain in operative relative position the several components of the machine tool **100** to be described. The base, in plan view as seen in FIG. **1**, resembles a letter "T," the upper bar of which is parallel to the X axis of the machine tool and the upright of which is parallel to the Y axis thereof. Upper surfaces of the base corresponding to the upper arms of the "T" provides pads **104** which carry means for positioning a plurality of tools, including in particular a main frame member **106** of the X axis component. A portion of the upper surface of the base forming the stem of the "T" provides a pad **108** upon which is mounted means for positioning a free end of an indefinite running length of strip material, which is to say in the instant embodiment the Y axis component of the machine tool. Between the pads **104** on the upper arms of the "T" and at the top of the stem, the base **102** provides a further pad **110** on which is mounted press means for actuating a tool positioned by operation of the aforesaid means for positioning tools, in other words, in the present embodiment the Z axis component of the machine tool **100**.

While the several components of the machine tool cooperate and act in conjunction in carrying out the method described, it will be convenient to describe the components separately and individually, discussing their mutual interaction as the description proceeds.

DESCRIPTION OF BLADES

Before proceeding with the description of the apparatus in detail, the description digresses briefly to a discussion of FIGS. **4** through **9**. FIG. **4** shows a free end E of strip material or stock S from which blades of the character with which the present invention deals are made. The strip material S may be of any suitable metal, ferrous or nonferrous such as brass, or substitute therefore. Conventionally, such blades are made of finished rolled stock of stainless steel of suitable grade and hardness.

FIG. **5** depicts a blade having a portion **112** which, in normal use, will be embedded about to the line **113** in the body of the tread forming portion of a tire mold (not shown) and secured therein by one or more of the holes **114**, **116** shown therein, in the conventional manner. Portion **118** in normal use will mold, in the tread of a tire, an impression conjugate to the form shown which includes the notches **120**, **121** and projections **122**. Notably the notches may take any desired form, may have parallel or nonparallel or angular sides, and may include square or rounded corners, as desired.

FIG. **6** shows another form of blade in which the blade is bent to form a plurality of adjoined panels **124**, **126** disposed angularly with each other.

FIGS. **7**, **8** and **9** show representative examples of the innumerable shapes and forms of blades capable of being produced with the method and apparatus according to the instant invention.

THE Z AXIS COMPONENT

According to the invention, actuating means are provided for actuating a selected one of a plurality of tools, the selected one tool being positioned proximate the free-end E of the strip being processed by means subsequently to be described. Shown in the drawing, and particularly in FIGS. **2** and **3** thereof, an actuating means in the present embodiment is provided by the X axis component of the machine tool **100** and includes a punch press **130** having a C-type frame secured to the pad **110** of the base **102**. Extending upwardly from its base **131** the press column **132** supports a head **134** in which is mounted a hydraulically reciprocable ram **136**, the direction of movement of the ram **136** paralleling the Z axis of the machine tool, which axis is perpendicular with respect to the X and Y axes of the machine tool. In the present embodiment the press **130** is of the type commercially available as the "-Dennison Multi-Press," Model TO8OL, available from the Dennison Engineering Division, American Brake Shoe Company, Columbus, Ohio, modified as described herein.

The press platen **138** supports a pedestal **140** to which is attached an anvil **142** which cooperates, in a manner described later herein, with the press ram **136** in actuation of individual tools or die sets positioned between the anvil **142** and the ram **136**. An opening **144** through the press platen **138** allows blades cut from the free end of strip material to fall into a chute (not shown) and thence to a receptacle. The invention

also contemplates provision for limited movement of the anvil **142** parallel to the X axis to accommodate an increased range of positioning along the X axis of individual shaping tools. On the nose or lower end of the press ram **136** there is attached a transfer arm **146** and a punch holder striker block **148**. The transfer arm **146**, affixed to and moving with the ram **136**, carries an actuating rod **147** connected to actuate the variable tap of a linear potentiometer (not shown) and conventional limit switches (not shown) activated at the limits of the stroke of the ram **136** upward and downward respectively. Variable voltage output from the potentiometer is amplified to modulate driving current in the solenoid valve **151** whereby the stroke of the ram **136** is limited to less than 1 inch.

Coordinated movement of the X axis and the Y axis components of the machine tool **100** serve to position a selected blade shaping tool and a free end of strip material S in predetermined juxtaposition with each other and with the Z axis, which is here the axis of the ram movement.

HYDRAULIC POWER SYSTEM

The apparatus includes a fluid pressure power system in the form of an oil hydraulic circuit **160**, shown in FIG. **10**. The circuit **160** includes the hydraulic pump **162** driven by an electric motor **164** connected to electric power supply means (not shown) and controlled by conventional motor control (not shown) which is housed with the control system to be described hereinbelow. The motor and pump, together with a supply tank **165**, are housed within the press column **132**. The pump **162** delivers oil at a predetermined pressure through a prefill line **166** to the hydraulic cylinder **168** which is used to operate the ram **136**. The oil pressure supply line **170** including a conventional filter unit, is controlled by a solenoid operated shutoff valve **172** responsive to a command signal from the control system described later herein. The branch pressure supply line **174** supplies oil at system pressure to the traversing or positioning drive means **75** which operates as a part of the Y axis component of the machine tool **100** and which will be described in greater detail subsequently. The branch pressure supply line **178** supplies oil at system pressure to the traversing or positioning drive means **180** which operates with and forms a part of the X axis component of the machine tool, which also will be described in greater detail. The means **175** and **180** both are, herein, electrohydraulic servo drive assemblies obtainable from the Datex Division, Conrac Corporation, 1600 So. Mountain Avenue, Duarte, California 91010.

The branch supply line **182** supplies oil at system pressure to the *a* axis component, a bending device rotation drive means **185**, and to a bend finger and jaw position adjusting means **190**. Both means **185** and **190** are herein likewise electrohydraulic servo drive systems obtainable from Datex Division, Conrac Corporation, previously identified, and which will be described in greater detail hereinafter. A further branch line **192** delivers oil at a suitably reduced pressure controlled by the pressure reducing valve **193** through a manifold mounting base **194** to a pair of clamp operating cylinders **200** and **205**, respectively, each controlled by solenoid valves **202** and **207**, respectively, and associated with clamp stock jaw means, which will be described in greater detail presently. Also mounted on the manifold base **194** is hydraulic operating cylinder **210** controlled by solenoid valve **212** which cylinder operates in conjunction with elevator adjusting means, also to be described subsequently. The branch line **214** delivers oil at the system pressure to an electrohydraulic servo valve **151** which controls the flow of oil to and from the cylinder **168**. The valve **151** operates in response to command signals received from the control unit or means for communicating command signals so that the ram **136** is actuated in response to the command signals received from the control unit.

Return lines **220** return oil to the supply tank **165** through the heat exchanger **222**.

THE Y AXIS COMPONENT

Turning now particularly to FIG. **2**, means for positioning the free end E of the strip S comprises a stock positioning assembly **250** adapted to receive a running length of strip material from a supply means such as the reel **252**. The strip may, if desired, be lubricated as it is drawn from the reel, by conventional means. The assembly **250** includes the slide bed **254** having guide means in the form of a pair of spaced parallel guide rails **256** disposed longitudinally along an intermediate portion of its top surface and a stiffening cover plate **260** disposed to form its lower surface. The rails **256** and the cover plate **260** are secured to the bed **254** by capscrews **262** through the plate **260**, the bed **254** and threaded into the rails **256**. At the outward (or leftward, as shown) end of the slide bed **254**, an upward extension **264** of the bed has a pair of flanges **266** carried on rock shaft means, the pivot pins **268**, received in sidewall portions **270** of the bracket **272** which is mounted on the pad **108** of the machine tool base **102**. At the inward (or rightward, as shown) end **274**, the bed **254** is adapted to receive first strip engaging jaw means **280**. The arrangement permits the bed **254** to be moved angularly about the pins **268** in a plane parallel to the plane defined by the orthogonal axes Y and Z enabling adjustment of the height or elevation of the jaw means with respect to the X axis for purposes more fully described later herein.

FIRST JAW MEANS

With reference additionally to FIGS. **11**, **12** and **13**, the first strip engaging jaw means in the form of a jaw assembly **280** comprises a lower jaw **300**, with a stock strip engaging surface **302**, fixed relative to the bed **254** and an upper jaw **302** having a strip engaging surface **303** movable toward and away from the lower jaw. The lower jaw **300** is secured by capscrews **304** in a jaw seat **306** provided in a buttress portion **308** of the bed **254**. The upper jaw **302** is mounted, for limited vertical movement, in a movable head **310** a dovetail **312** of which engages a dovetail slide **314** carried by the housing **316** secured to the upper surface **317** at the end **274** of the bed **254**. The jaws **300** and **302** are adapted to support a portion of the strip S with a free-end E thereof extended cantileverly outward therefrom. Extending upwardly through an opening **318** in a cross-member **320** of the housing **316** is a bushing **322** having a flange **324** which is seated on an upwardly facing surface **326** of the head **310**. Immediately above the bushing **322** a clamp wedge **328** having a cylindrical boss **330** generally coaxially aligned in face-to-face relationship with the bushing **322** is secured thereto by a bolt **332**. A compression spring **334** extends between the face of a counterbore **338** in the cross-member **320** and the opposed face **340** of the wedge **328** and is located generally concentrically with the bushing, the boss and the bolt. The spring **334** serves to urge the movable jaw head **310** and the jaw **302** upwardly away from the lower jaw **300**. Upward movement of the movable jaw head **310** is adjustably limited by engagement of the upper angular face **342** of the wedge **328** with an opposed mating angular face **344** of a horizontal wedge **346** movable along the horizontal surface **348** provided on the upper yoke **350** of the housing **316**. Adjustment of the limit of upward movement of the head **310** and movable jaw **302** is provided by an adjustment of the limits of horizontal movement of the upper wedge **346** with respect to the stroke of a piston within the fluid power cylinder **200** to which piston the wedge is connected, providing the advantage of preventing the insertion between the holding jaws **300**, **302** of stock greater in thickness than the stock for which the machine is preset to accommodate. The mechanism by which this adjustment is achieved comprises a nut **354** having a turnbuckle effect provided by right and left hand threaded holes coaxial therein which holes receive respectively a threaded tang **360** affixed to the clamp wedge **346** and a threaded piston rod end **362** of the cylinder **200**. Mounted concentrically on the nut **354** for corotation therewith is a gear **366**

meshed rotatively with a pinion **370** of pinion shaft stock which also carries an adjustment knob **372** by which the thickness of the strip stock to be processed can be preset into the mechanism manually or otherwise. The pinion shaft **370** is journaled in plate **374** secured on the yoke **350**. An intermediate shaft **376** journaled in the plate **374** carries a gear **378** meshed corotatably with the pinion **370** and also carries a graduated dial **380**. Attached to the plate adjacent the periphery of the dial **380** is an index marker **382** to which the graduations of the dial **380** are referred. A potentiometer **384** is mounted on the plate **374** with it rotatable shaft **386** extending thorough the plate to carry a gear **388** in rotational mesh with the gear **378**. Adjustment of the knob **372** thus operates to set the limits of upward movement of the jaw **302** and to set the potentiometer **384** for purposes set forth later herein. Rotation of the adjustment knob **372**, and the pinion shaft **370** causes a timed rotation of the gear **366** and the nut **354** to which it is attaches so to move the clamp wedge **346** with respect to the piston rod end **362** as to relocate the end points of movement of the wedge **346** with respect to the travel of the piston in the cylinder **200**. Rotation of the piston rod is prevented by a pin **390** fixed in the piston rod end **362** and engaging a key way **392** in the yoke **350**. It will be apparent that actuation of the cylinder **200** to extend the piston rod **364** will, as seen in FIG. **12**, move the clamp wedge **346** to the left and thereby move the wedge **328** downwardly together with the movable jaw **302** and head **312**. Actuation of the cylinder **200** to retract the piston and rod **364** will cause the clamp wedge **346** to move to the right whereupon the compression spring **334** urges the first wedge member **328** upwardly to move the movable jaw **302** and head **312** likewise upwardly.

For purposes to be more fully described later (see also FIG. **29A**), the lower jaw **300** includes a bending nose portion **394** of particylindrical form disposed about a cylindrical axis **395** and having a cylinder radius not greater than the minimum radius or downward bend intended to be made. Likewise the upper jaw **302** is provided with a bending nose portion **396** of particylindrical form about the cylinder axis **397** at a radius not greater than that of the smallest radius of upward bend anticipated. Generally the nose portions **394**, **396** have the same radii. The axes **395**, **397** are parallel to the stock engaging surface **301**, **303** respectively of the jaws **300**, **302**, and spaced therefrom such that the nose cylindrical surfaces are smoothly tangent to the respective surfaces **398**, **399**.

ELEVATOR CAM ASSEMBLY

The elevator means are provided, in the present embodiment as shown by FIGS. **2** and **14**, by the cam assembly and control means **400**, to adjust the position of the first strip engaging jaw means **280** transversely with respect to the X axis of the machine tool, and particularly to elevate or lower the first jaw means **280**, and the free end of the strip therein, up or down with respect to the bending device described subsequently herein. The elevator cam assembly **402** is mounted on the pad **404** of the machine tool base **102**. The assembly **402** includes the cam support frame **405**, a cam shaft **406** rotatably supported in bearings carried by the side members of the frame **405** and a cam **408** corotatable with the shaft **406**. The cam surface **410** of the cam **408** engages a cylindrical cam follower or roller **412** mounted on a shaft **414** carried in the upright portions of the roller bracket **416** which is secured to the cover plate **260** of the bed **254**. Also mounted on the pad **404** adjacent to the frame **405** is a hydraulic cylinder **210** having a piston rod **418** terminating in a clevis **420** which receives a pin **422** therethrough. The outward ends of the pin **422** are received in slots **424** in the upright portions of the bracket **416**. The cam shaft **406** is coupled by flexible coupling **428** to the floating shaft **430** connected with the output shaft **440** of the reduction gear set **442** by the flexible coupling **444**. The cam surface **410**, is provided with a constant radius, or cylindrical portion, which operatively engages the roller **412**, since in the present embodiment, the bending nose axis **395** does not require repositioning to accommodate changes in stock thickness, for downward bends in the stock. Upward bends in the stock, on the other hand, are made in cooperation with the upper jaw **302**, the elevation of which is changed in accordance with the thickness of the stock to be bent. The cam surface **410** has a second portion with progressively decreasing radius or cam ramp, which engages the roller **412** to position the bending nose axis **397** into collinear alignment with the rotation axis of the bending device as will be further described later herein. It will be appreciated that rotation of the shaft **430** will move the cam surface **410** to raise or lower the bed **254** and the jaws **280** so that the nose portion axes **395** and **297** are suitably positioned with respect to the X axis. As will appear later herein, the rotation of the cam **408** is in timed relation with and responsive to the command signals communicated to a finger and jaw adjustment drive means **190**.

The clamp cylinder operates to hold the roller **412** and the cam surface **410** in firm contact with one another during forming operations upon the strip, and to reduce the pressure of such contact during rotational movement of the cam. The cylinder control valve **212** is actuated in response to signals emanating from the control system presently to be described.

STOCK POSITIONING CARRIAGE ASSEMBLY

As may be seen in FIGS. **2**, **15** and **16**, the stock positioning assembly **250** further includes carriage means **450** mounted slidably on the guide rails **256** of the bed **254** by linear bearings **452** secured in foot brackets **454**. The carriage **450** is movable between a first limit position, shown in phantom outline, at the outward, or leftward end **264** of the bed where its leftward movement is arrested by a spring snubber **456** abutting the stop **457** and a second limit position, as shown in full outline, at the inward or rightward end **274** of the bed where its rightward movement is arrested by engagement of the spring bumper **458** and stop **459**. Between the two described limit positions the carriage **450** may be moved in substantially infinitesimal steps to any location along the Y axis. In the embodiment being described, the movement of the carriage is nominally about 5 inches.

SECOND JAW MEANS

Referring additionally to FIGS. **16** and **17**, second stock engaging jaw means is provided by a translating or moving jaw assembly **460** comprising a subbase **462**, secured to the carriage surface **463**, and a yoke frame **464** extending upwardly over the subbase to support the fluid power cylinder operator **205**, the piston rod end **468** of which is attached by a clevis **470** to the yoked end **472** of an upper pivotally mounted jaw member **474** which carries at its other end a jaw **476** opposed to a lower jaw **478** affixed to the subbase **462**. The jaws **476** and **478** are adapted to grip a portion of the strip S and to support cantileverly a free-end E so that by movement of the carriage **450** the end is suitably positioned in successive fixed locations with respect to the X and Z axes in response to signals as will be further described. A pair of flanges **480**, **482** standing upwardly from the subbase **462** each has a pin **484** which pins are received in a pair of coaxially mounted bushings **486** seated in the upper jaw member **474** and support the member for the pivotal movement thereof about the pins **484** by action of the cylinder **205**. To register the width of the strip S accurately in position, a pair of fixed guide rollers **490**, rotatable about substantially vertical axes, are mounted upon bosses **492**, extending upward from the subbase **462**. A pair of adjustably mounted guide rollers **494**, rotatable about vertical axes, are carried by blocks **495**, on studs passing through slots **496** in a yoke **497** and urged transversely with respect to the Y axis under the influence of the compression springs **498**. Extending transversely of the Y axis and below the path of the strip is a shaft **500** mounted for rotation in the flanges **480**, **482** respectively and secured therein against axial movement by the thrust collars **504** bearing upon the surfaces of the flange **480**. A portion **510** of the shaft is provided with screw

threads which are threadably engaged in a tapped hole **512** located in the central portion of the bar **514** at the opposite ends of which the bolts **520** extend through the holes **524**, through the springs **498** and are threadably secured into the blocks **495**. Rotation of the shaft **500** by the crank **532** enables movement of the bar **514** and the adjustable guide rollers **494** toward and away from the fixed guide rollers **490**, so as to provide a desired degree of lateral restraint against the edges of the strip material passing through the jaw assembly **460**. Actuation of the cylinder operator **205** pivotally moves the upper jaw member **474** so as to move the jaw surface **476** toward the lower jaw **478** to grip a portion of the strip for movement with the carriage **450**, or away from the lower jaw **478** to release the strip and permit independent relative movement between strip and carriage **450**.

STRIP STRAIGHTENING OR LEVELING

As may be seen in FIGS. **15** and **18**, the Y component includes, on the upper surface **463** of the carriage **450** and for movement therewith, a strip straightening, leveling device **550**. Self-alignment, castering, or pivoting means are provided for the straightening device **550** and comprise a stud **552** affixed upright in the transversely adjustable bracket **554** which is secured to the carriage **450** by the capscrews **556**. The lower frame member **558** is suitably bored to receive that stud **552** and pivot therearound and is restrained against vertical movement by the clamp washer **560** and nut **562**. Traversing movement of the device **550** relatively with respect to the strip S is enabled to straighten the material without imposing undesirably lateral forces on the strip being straightened. Four parallel rollers **563** engageable with the underside of the strip S on the upper side thereof, are rotatably mounted in the upper frame member **566**. The member **566** is hinged to the lower frame **552** about the hinge pin **568** received in the ears **570** of the lower member **552**. The upper rollers **564** are individually or collectively adjustable vertically with respect to the lower rollers **563** by the operation of a plurality of parallel rotatable cross shafts **580** to **584** inclusive, carried by the upright walls **572**, **574** of the upper frame member **566**.

The cross shafts **580** and **581** respectively have corotatably mounted thereon the gears **586** and **588**. The gear **586** on the shaft **580** is rotatably meshed with a gear **590** on the shaft **582** and with the gear **592** on the shaft **583**; the gear **588** on the shaft **581** is corotatably meshed with the gear **592** on the shaft **583** and with the gear **594** on shaft **584**. Shafts **580** and **581** are also longitudinally slidably mounted in the walls **572** and **574**, being urged forward (to the right in FIG. **18**) by the springs **596**, the stop collars **598** mounted on the shafts and bearing against the innerface of the wall **572**. **582**, cross-shafts **582**, **583**, and **584** each carry two bevel pinions, **600** and **602**, which are engaged respectively with bevel pinions **604** and **606**, each of which is secured to a screw **608** rotatably journaled in the web **610** of the upper frame member **570**. Each of the six screws **608** carries a thrust collar **612**, bearing against the undersurface of the web **610**. EAch screw **608** is threadedly received in a roll chuck **614** each of which respectively receives a journal of one of the upper rolls **564**. Thus, rotation of the crank **616** mounted on the shaft **583** is operable to raise or to lower the upper rollers **564** together. By moving one or the other, or both, of the shafts **580** or **581**, toward the left, the gear **586** or the gear **588**, or both, may be disengaged from the gear **592** on the shaft **583** so that independent adjustment of the rollers **564** can be made.

The lower frame member **552** is provided with a screw **640** which carries a wedge clamp **642** movable inwardly into clamping engagement with a sloped surface **644** provided in the upper frame member **566** or outwardly clear of clamping engagement by actuation of the crank **646** carried by the splined end **648** of the screw **640**. The shafts **582**, **583**, **584** are provided with graduated dials **650**, secured corotatably thereon. Index markers **654** are mounted on the outer surface of the wall **572** adjacent the periphery of each of the dials **540**, enabling the graduations of the respective dials to be aligned to the markers.

As will later be described in greater detail, movement of the carriage **450** away from the first jaw means **280** is operable to straighten, level and tension a portion of the strip engaged by the rolls of the device **550** as it is moved relative to the strip held by the first jaw means **280**. Straightening of the strip takes place close to the free end but effectively isolated from the shaping operation thereon without use of an intermediate loop or festoon and without need for an independent drive to the straightening device or to the rollers. The pivotal mounting of the device effectively reduces tendencies of straightening rolls to misguide or redirect the strip alignment.

STOCK POSITIONING DRIVE

Referring now to FIGS. **2**, **15** and **16**, traversing or positioning drive means for moving the carriage **450** comprises the electrohydraulic servo drive assembly **175** which in includes a hydraulic motor **700** affixed to the end wall **702** of the bracket **272**. An output shaft **704** of the motor **700** is connected by a zero backlash coupling **706** to one end of a precision ball lead screw **710** which is supported for rotation without axial displacement in bearings mounted in the bed end portion **264**. The threaded portion **714** of the lead screw **710** extends longitudinally of the bed **254** parallel to the guide rails **256** and is threadedly engaged in a precision ball screw nut **716** secured to the web **718** by the bolts **720** screwed into the plate **722** borne by the web **724** of the carriage **450**. Rotation of the lead screw moves the carriage **450** toward or away from the X axis along a path parallel to the Y axis of the machine tool **100**.

THE X AXIS COMPONENT

Referring now particularly to FIGS. **3**, **19** and **20**, means for positioning tools, in the present embodiment the X axis component of the machine tool **100**, comprises guide means in the form of a frame member **106** secured upon the pads **104** of the base **102** and bridging over the platen **138** of the press **130**. The frame member **106** provides track means here including the channel **800** and the guide bar **802**, both extending substantially from one end to the other of the frame member **106** parallel to the X axis. Mounted upon the frame member **106** for movement along the track means parallel to the X axis are the carrier **810** and bending device **820**. The tie member **822** is fixed to the carrier **810** and to the bending device **820** and maintains a fixed spaced relation therebetween. The carrier **810** has a pair of brackets **824**, on each of which are affixed guide rollers **828** in engagement with the guide channel **800** and includes a pair of pedestals **830**, **832** each having a slide bearing **834** engaging the guide bar **802**. The bending device is described in greater detail later herein.

In the embodiment described the bending device **820** is adapted to move transversely with respect to the free end of the strip and parallel to the X axis, i.e., the path of movement of the carrier **810**. It is within the contemplation of the invention that a bending device be mounted for movement in any suitable path between a position for engagement with the free end of the strip and a second position removed from such engagement. For reasons which will presently become apparent, several advantages are obtained from the herein described arrangement.

THE TOOL CARRIER

The tool carrier **810** supports a plurality of shape altering tools. The carrier **810** has an open passage **852** extending into and along the carrier **810** parallel to the X axis and to the Y axis to admit the free end of the strip as the carrier **810** is moved transversely of the strip and the Y axis. The shape alternating tools comprise a plurality of punch and die sets **860**—**872** inclusive.

Digressing briefly from the description of the X component, it should be noted that punch and die sets of any particular configuration suitably adapted to remove increments of the

total outline configuration of a desired blade may be employed. FIG. 21 shows configurations of punch and die sets which are used advantageously in the practice of the invention. The letters A through M in FIGS. 20 and 21 represent the stations at which the particular punch sets are employed and correspond to the stations as lettered in FIG. 20. Station A identifies the cutoff station discussed later herein. Stations B and C are employed to provide holes such as the holes 114, 116 shown in FIGS. 6—9. Stations D, E, F, G, H, J, K, L are employed to perform material removal in increments resulting in the notches, serrations and projections such as are depicted in the blades shown in FIGS. 6 through 9.

Manufacture of blades of the type shown and described is not necessarily limited to removal of material from the strip. The punch and die sets may include, when desired, sets adapted to perform deforming, cupping, dimpling, coining and like alterations of shape of the strip material.

PUNCH AND DIE SETS

Turning now to FIG. 22, a punch and die set representative of the several sets, 861—870 inclusive, employed in the practice of the invention, includes a punch assembly 880 mounted in the upper body portion 882 of the carrier 810 above the passage 852 and a die assembly 884 mounted in the body portion 886 below the passage 852. The punch assembly 880 includes a punch 890 secured in the shank 892 received within the punch holder 894 and within the stripper holder 896. The stripper actuating spring 898 is disposed around the shank 892 and within counterbores 900, 902 respectively in the punch holder 894 and the stripper holder 896, both holders being slidably received in the sleeve 904 snugly fitted in and extending through portion 882 of the carrier 810 normal to the plane defined by the X and Y axes. The stripper plate 908 is secured in the stripper holder 896 by a retaining ring 910. The lifter plunger 912 is slidably received in a flanged bushing 914 secured in the portion 882 with its axis parallel to and spaced from the punch axis 916 and has a counterbore 918 receiving the lifter spring 920 extending into the counterbore 922 and to the ends of the respective counterbores. A stud 926 fixed in the punch holder 894 is engageable with the lifter plunger 912 and with the stop 930 fixed to the top of the carrier 810 by a cap screw or the like (not shown).

The die assembly 884 of the set shown in FIG. 22 includes the die button 934 attached to the die holder 936 which is slidably received in the bushing 938 secured in and extending through the lower portion 886 in coaxial alignment with the punch assembly 880. The die holder 936 is threaded internally of the counterbore 942 and therein receives the threaded male end of the anvil spacer 946, the flange 948 of which is engaged by the cantilever die spring 950 which serves to lift the die assembly 884 slightly to an idle position to clear the anvil 142 during movement thereover of the carrier 810, and to permit the die assembly 884 to move downward against the anvil 142 into a working position.

ROTATABLE PUNCH AND DIE SETS

INcluded in the plurality of tools supported by the carrier 810 are punch and die sets 871, 872 which are rotatable about axes 971, 972 respectively normal to the plane defined by the X AND Y axes, which is to say the plane defined by the direction of movement of the tool positioning means and of the stock positioning means. The rotatably die sets 871, 872 are shown in greater detail in FIGS. 23 and 24. There may be any number of rotatable die sets; in the present embodiment two have been found to be convenient. The set 872 comprises a punch assembly 1000 including a punch 1002 s3cured to a punch shank 1004 which is screwed into the punch holder 1006 and there secured by a lock screw (not shown). The punch holder 1006 includes a counterbore 1008 and a cylindrical skirt 1010, both of which are coaxial with the shank 1004. A stripper 1012 is secured by the snap ring 1014 in the stripper guide 1016 which has an internal flange 1018, one face of which abuts a face of an enlarged portion 1024 of the shank 1004. Disposed about the shank 1004 from the bottom of the counterbore 1008 to the other face of the internal flange 1018 is a compression spring 1030. The outer cylindrical surfaces of the skirt 1010 and of the guide 1016 are fitted for sliding and for rotation within a pair of bushings 1036, 1038 secured in a bore 1040 of the upper portion 882 of the carrier 810. Corotation of the stripper 1012 and its guide 1016 with rotation of the punch assembly, in the manner to be described, is assured by the snug fit of the punch 1002 within the stripper 1012 and by the frictional engagement of the flange 1018 and face 1022.

The die assembly 1050 of the rotatable punch and die set 872 includes a die button 1051, conjugate in form to its associated punch 1002, which is supported by the die support 1052 having a female screw thread receiving a male threaded coupling 1056 having a flange 1058. (Relative rotation of the two threaded members 1052, 1056 provides adjustment of the height to which the die button 1051 is supported in the die assembly to provide for the regrinding of the die button 1051 as required.) The die support 1052 is received within a flanged bushing 1062 and has a key 1064 slidable in the key way 1066 in the flanged bushing 1062. The flanged bushing 1072 is counterbored to receive the flange 1058 of the coupling or bushing 1056 and a flange of the support ring 1068. The support ring 1068 is in turn secured to the flange 1070 of the bushing 1062 by capscrews so that the ring 1068 clamps the coupling flange 1058 against the counterbore seat 1074 to prevent relative movement therebetween. The bushing 1062 is rotatably received in sleeve 1076 seated in the bore 1078 in the portion 886 and coaxially with the bore 1040.

Secured to the punch assembly 1000 by capscrews is a gear 1080 rotatably meshed with an antibacklash-type driving gear 1082 mounted upon a jack shaft 1084 carried in bearings 1086, 1088 seated in a bearing block 1090 affixed to the carrier 810. A substantially identical antibacklash gear 1092 is mounted at the other end of the jack shaft 1084 which gear 1092 in turn engages a gear 1094 corotatably affixed to the die support ring 1068 of the set 872.

The jackshaft 1084 also carries, corotatably mounted thereon, the bevel gear 1096 which is drivingly engaged by the bevel pinion 1098 on a bevel pinion shaft 1100 rotatably supported by a pair of bearings 1102 in the bearing housing 1107 affixed to the tool carrier 810. The bevel pinion 1098 is drivingly connected by a floating drive shaft 1110 with flexible coupling 1111 to a shaft extension 1112 provided in the bending device 820 to be described in more detail below.

The punch and die set 871 has an antibacklash gear 1120 corotatably affixed to its punch assembly 1122 (which is identical to the punch assembly 1000, except as noted) in meshing engagement with the gear 1080. The die support ring 1124 of the die assembly 1126 likewise has an antibacklash gear 1128 drivingly engaged with the gear 1094 on the support ring 1068. The arrangement insures that the punch and the die of a particular set can be rotated through the same angular displacement. By rotating the punch and die set the sidewalls of a notch or projection in a particular blade may be formed at any desired angular relation with the Y axis; large radii may be cut; and the versatility of the apparatus is increased.

Return of the punch assemblies 1000 and 1122 to a rest or idle position following actuation is provided by the spring loaded plungers 1140 bearing on the gears 1080 and 1120 so as to urge the punch assemblied 1000 and 1122 upward to rest against the stop buttons 1148 carried by the stop blocks 1150. Except as noted, the die assemblies 1050 and 1126 are identical.

The spring 1152 urges the die support ring 1068 and the die assembly 1050 upward into the carrier portion 886 slightly to insure that the die support ring 1068 can pass freely over the anvil 142. It is a feature of the present invention that any number, including none, of the rotatable die sets may be used and placed in any position in the carrier. In the present embodiment two die sets have been found advantageous, the

punches being conjugate respectively with the mating dies and having the forms shown in FIG. 21 at stations L and M.

As will become apparent later herein, it is within the scope of the present invention, and within the capability of the apparatus provided thereby, to employ one or more punch and die sets to nibble material from the strip being processed. It is a particular advantage that repeated strokes of a particular set can be occasioned by actuating means in response to the command signals communicated thereto and can create outline shapes in blades or like parts which are not limited to the shapes conjugate to the particular punch configurations shown but which shapes may be made up of a plurality of incremental cuts of the material of the strip.

It will be evident also that the outline of the punch and of the matching die of any rotatable set, according to the present invention, may be of any configuration; full advantage of the rotation feature, however, is achieved with punch and die configurations which are other than circular, i.e., any noncircular configuration, examples of which are shown at stations L and M of FIG, 21.

THE CUTOFF ASSEMBLY

Making reference now to FIG. 25, the tool carrier 810 at Station A also supports means for severing the free-end E, in the form of the cutoff assembly 860. The cutoff punch portion 1202 thereof is carried by the upper portion 882 and includes the shear or punch 1204 secured in the seat 1206 of the punch holder 1208 by capscrews 1209. The threaded stud 1210 of the holder 1208 is secured in the mating threaded hole in the head 1214. The holder 1208 is slidably received in the body 1216 which also slidably receives the stripper member 1218 having a foot 1220, an intermediate flange 1222 and a terminal flange 1224 disposed between the faces of an annular groove 1230 in the head 1214. A pair of compression springs 132 extend between the face of the intermediate flange 1222 and a pressure plate 1238 loosely fitted around the stud 1210 beneath the head 1214. The counterbore 1239 in the body 1216 receives therein a compression spring 1240 bearing on the plate 1238.

The cutoff die portion 1250 of the assembly is mounted on the lower portion 886 of the carrier 810 by and for pivotal movement about the shoulder screw 1252 and is secured by the retaining screw 1254. The cantilever spring 1256 affixed to the lower carrier portion 886 bears on the lower surface 1258 of the cutoff die portion 1250. The cutoff die or shear 1260 is removably fixed into the seat 1262 by the capscrew 1264.

TOOL POSITIONING DRIVE

At the left end of the frame member 106, as seen in FIGS. 3, 19 and 20, the traversing or positioning drive means 180 includes a hydraulic motor 1300 supported by the end wall 1302. The output shaft 1304 of the motor is connected by a zero backlash flexible coupling 1306 to the drive end 1310 of a precision ball lead screw 1312 which is supported for rotation without axial movement in suitable bearings (not shown) mounted within the housing 1318 of the frame member 106. The threaded portion 1320 of the lead screw 1312 is threadedly engaged by a precision ball screw nut 1322 affixed to the bracket 824 of tool carrier 810. The opposite end 1324 of the lead screw 1312 is supported by an outboard bearing 1326 carried in the bracket 1328 supported from the frame 106.

Movement of the plurality of tools along the X axis is precisely controlled by the drive means 180 through the engagement of the ball nut 1322 with the ball lead screw 1312 in substantially infinitesimal increments from the position shown in FIG. 3 where the bracket 830 engages a cushion stop member 1330, limiting overtravel toward the left, as seen in the figure, and a position to the right where the bracket 832 of the carrier means 810 engages a similar cushion stop member 1331. The two limit positions described are spaced sufficiently apart so that any individual tool can be positioned precisely with respect to the Y axis and to the free end of the strip as the latter is positioned by the Y axis component of the machine tool. As previously noted herein, the bending device 820 is maintained in spaded relation with the carrier 810 and is also moved along the X axis by operation of the lead screw 1312 and nut 1322.

THE BENDING SYSTEM AND DEVICE

Of the plurality of tools contemplated by the invention to shape the free end of a strip, one is a bending device. Shown in FIG. 3, the bending device 820 is connected to the carrier 810 by the tie bar 822 for movement on the track means of the frame member 106 in spaced relation to the carrier 810. A preferred form of the bending device 820 is shown in greater detail in FIGS. 26, 27, 28, 29 and 30.

The body or housing 1350 of the device 820 is provided with a flange 1352 having a pair of cam rollers 1354 engaging the channel 800 and with a pair of foot brackets 1356 each having a slipper bearing 1360 mounted to slide along the guide bar 802.

THE FINGER EXTENDING MECHANISM

The bending device 820 also includes means for extending and retracting a finger and means for rotating the finger about an axis transverse to the Y axis. Means for extending the finger, referring to FIG. 28, includes a head 1400 mounted rotatably in suitable bearings 1402, 1404 in the housing 1350; means for adjusting the finger to and away from a predetermined spacing or distance from the axis 1414 includes a pair of slideways 1406, 1408, each receiving respectively one of an allochiral pair of bending fingers 1410, 1412 for sliding movement therealong. The slideways 1406, 1408 are oriented at slight angles equal and opposite with respect to the rotational axis 1414 of the head 1400 and specifically at slopes of approximately one to eight.

It will be appreciated that other expedients may be substituted to provide the requisite adjustment of one or both of the fingers 1410, 1412 in distance from the rotation axis 1414. For example, the invention also contemplates use of a series of preadjusted fingers which can be selectively secured in a bending device. Each of the fingers 1410, 1412 is provided along one of its sides with a gear rack 1416, 1418 each of which racks engage a rack pinion 1420 carried on pinion shaft 1421 mounted in bearings 1423, 1425 in the head 1400 to be perpendicular to the plane defined by the directions of movement of the fingers. The arrangement is such that by rotation of the pinion 1420 one of the fingers 1410, 1412 is extended, along its slide, outwardly from the head 1400 while the other of the fingers 1412, 1410 is simultaneously retracted into the head 1400. A portion of each of the fingers has adjacent its outward end a surface 1422, 1424, respectively, parallel to the axis of rotation 1414 of the head 1400, each of the surfaces 1422, 1424 being engageable with a surface of a free-end E of the strip held in the first jaw means 280, previously described. Extending one of the fingers thus moves, or adjusts, the spacing of the finger and the working surface 1422 or 1424 with respect to the axis 1414. Each of the fingers 1410, 1412 is provided with a groove 1426 which receives a spring 1434. The ends 1436 of the springs 1434 engage pins 1438 anchored respectively in the grooves 1426 in such a manner that each of the springs 1434 urges the respective gear rack 1416, 1418 against the rack pinion 1420 during at least a part of the movement of the respective fingers 1410, 1412.

As may be seen in FIGS. 28 and 29, each of the fingers 1410, 1412 is so shaped as to have in its outwardly extending portion, in cross sections normal to the axis 1414, an outline form including surfaces 1440, 1442 generally normal to the strip engaging surfaces 1422, 1424, a U-shaped clearance groove 1444 having a side 1446 parallel to the outer plane surface 1448 and a side 1450 flared angularly upwardly and outwardly of the bottom 1452 of the U to blend with the surface

1440. From the outer surface 1442 a side 1454, diverging angularly from the first flared side 1444, terminates at the rectilinear surface 1456. The sides 1454, in the rest or O angle position of the head 1400, lie approximately parallel to the respective angular surfaces 398, 399 of the jaws 300, 302. The clearance grooves 1444 permit closely spaced successive upward and downward bends in the end of the strip being processed. It is a notable advantage of the bending system of the present invention that bends can be performed not only in close succession but also either upward or downward, and without it being required to turn the stock strip material over.

THE BENDING DEVICE

The *a* axis component includes drive means connected to the bending device to effect rotation of the fingers 1410, 1412 through a predetermined angle about an axis transverse to the Y axis, and comprises an electrohydraulic servo drive 185, including a hydraulic drive motor 1470 carried by the frame member 106, as shown in FIG. 26. Referring now particularly to FIGS. 26 and 30, an output shaft 1472 of the motor is coupled to a splined shaft 1474 by a zero backlash coupling 1476. The splined shaft 1474 extends to and is engaged within a ball spline sleeve 1478 for positive corotation therewith and for free axially relative movement between the splined shaft 1474 and the sleeve 1478. The spline-sleeve 1478 is fixed within a hollow pinion shaft 1480 mounted rotatively in the housing 1350 and carrying the pinion 1482 which engages a gear 1484 mounted on the intermediate shaft 1485. The intermediate shaft, also rotatably mounted within the housing 1350, carries the pinion 1486 which meshes with the gear 1487 secured to the rotatable head 1400 so that rotation of the splined shaft 1474 causes a rotation of the head 1400 of the same rotational sense as that of the shaft 1474. The intermediate shaft 1485 is provided with a takeoff or shaft extension 1112 by which its rotation is communicated to the previously described bevel pinion shaft 1100 of the rotatable pinch and die sets 870, 871.

The rotation of the head 1400 in the bending device 820 and the rotation of the one or more rotatable punch sets 870, 871 are in exact timed relation with one another and responsive to the *a* axis control.

The gear 1484 on the intermediate shaft 1485 also meshes with the gear 1488 on the spool 1490 which is mounted to be freely rotatable upon the shaft extension 1492 of the head 1400 and which spool also carries a pinion 1494 which meshes with the planetary pinions 1496 rotatably mounted on pins 1498 secured in the planet carrier or spider 1500 carrying a gear 1502 and which spider is freely rotatable upon the shaft extension 1492. The planetary pinions 1496 also mesh with the internal gear 1504 of the internal-external gear ring 1506 which is supported by the antifriction bearing 1507 for rotation on and relative to the head 1400. The external gear 1508 of the ring 1506 in turn engages the pinion 1510 carried by the hollow pinion shaft 1512 mounted rotatably in the housing 1350.

The pinion 1510 being stationary and holding the ring 1506 stationary, rotation of the shaft 1474, and of the head 1400, causes the spool 1490 to rotate, in the same sense as the head; the pinion 1494 on the spool 1490 causes rotation of the planetary pinions 1496 on the pins 1498 and rotation of the spider 1500; the spider gear 1502 then causes rotation of the jack shaft pinion 1514 relative to the housing 1350 exactly equal and opposite to the orbital rotation of the pinion 1514, relative to the housing 1350 induced by the rotation of the head 1400, carrying the shaft 1516 about the axis of rotation 1414 of the head 1400. The arrangement insures that rotation of the head 1400 is fully independent of rotation of the pinion 1420.

As will be apparent from FIG. 28, rotation of the pinion 1420 in its engagement with the respective racks 1416, 1418 of the bending fingers 1410, 1412 will retract one finger and extend the other. Driving means 190 in the form of an electrohydraulic servo drive, described elsewhere herein, is connected to the pinion 1420 and operable to extend one and retract the other of the fingers. As shown in FIG. 26, the means 190 includes a hydraulic motor 1530 having an output shaft 1532 which is coupled by a zero backlash flexible coupling 1534 to the input shaft 1536 of the reduction gearset or gearbox 442 which is provided with two output shafts, Coupled to the output shaft 1540 by a zero backlash flexible coupling 1542 is a second splined shaft 1544 which extends to and is slidably received within a ball-spline sleeve 1546 and is positively corotatable therewith. The sleeve 1546 is keyed for corotation with the hollow pinion shaft 1512, the pinion 1510 of which engages the external gear 1508 of the ring 1506 carried by the rotatable relative to the bending head 1400. The internal gear 1504 of the gear ring 1506, as before, is engaged with the planetary pinions 1496 carried on the spider 1500 which carries the gear 1502. The splined shaft 1474, intermediate shaft 1485, the spool 1490, the gear 1486, and the head 1400, being stationary, planetary pinions 1496 and the spider 1490 are caused to rotate by rotation of the splined shaft 1544, pinion 1510, and the gear ring 1506 so that gear 1502, in mesh with pinion 1514, causes rotation of the bevel pinion shaft 1516, the bevel pinion 1564, the bevel gear 1566, the rack pinion shaft 1421, and its pinion 1420. Depending upon the direction of rotation of the shaft 1544, one of the fingers 1410, 1412 is extended while the other finger 1412, 1410 is retracted respectively outward from or into the bender head 1400.

As will be evident from the foregoing description, the bender head 1400 and its drive shaft 1474 are maintained in constant timed relation one to the other. The rack pinion 1420 and the bender finger extension splined drive shaft 1544 are maintained in constant timed relation one to another. The differential gear action, provided by the floating ring 1506 with gears 1504 and 1508 and the planetary train described, operates to maintain both constant relationships and provides means to prevent rotation of the rack pinion 1420 about its own axis during the rotation of the bender head 1400 so as to maintain the extension of one or the other finger a predetermined amount, while at the same time enabling the rotational movement of the bender head 1400 or the extensional movement of one of the bender fingers 1410, 1412 independently of one another.

As has been noted in connection with FIG. 23, the tool carrier includes rotatable punch and die sets 870, 871 rotatable by the rotation of the bevel pinion shaft 1100. The arrangement described has the advantage of dual use both of the drive motor and the control means therefor, eliminating an independent drive and control to the rotatable punch and die sets.

A notable advantage obtained by mounting each of the drive means stationary on the machine tool is the elimination of troublesome flexible hydraulic and/or electrical connections which would otherwise be required if drive means were mounted for movement together with the carrier being moved. The arrangement permitting the conjoint movement of the tools on a common slide permits the use of a single drive means to position the selected tool as required with respect to the strip material and the Y axis. The use of splined shafts slidably received in the sleeves as described likewise enables the motive means to remain fixed with respect to the machine frame during movements of the tool carrier and the bender device.

To provide increased rigidity and to resist the reactive torque resulting from the resistance to bending by the strip material, the housing 1350 of the bending device 820 is provided with a bushing 1580, As the bending device 820 is moved into its position proximate the free end of the strip, as shown in FIG. 26, preparatory to bending the strip either up or down, the pin 1582 secured to the tool slide frame 106 by the bracket 1584 enters snugly into the bushing 1580.

The housing 1350 includes overtravel safety means including a boss 1586 in which is secured a spring cushioned limit stop plunger 1588 having angularly disposed end surfaces 1590, 1591. The rotatable head 1400 carries a lug 1592 en-

gageable with the surfaces **1590**, **1591**. Rotation of the head **1400** in one or the other direction through its maximum angle, brings the lug **1592** against one of the surfaces **1590**, **1591** of the plunger to prevent accidental overtravel.

THE CONTROL SYSTEM

In accordance with the invention the apparatus includes means for storing and communicating a predetermined sequence of command signals to the several components of the machine tool, including the strip material positioning means (Y axis component), and the tool positioning means (the X axis component). Shown in FIG. **31**, the means for storing and communicating command signals here includes the numerical control (NC) unit or device indicated generally by the numeral **1600**. The NC unit **1600** includes an eight channel tape reader **1602** and spooler **1604** available commercially under the name Remex, from Datex Division, Conrac Corporation, previously identified. The device **1600** provides means or memory device for storing a prepared program including a predetermined sequence of perforations in the tape **1606** which are detected or read by the reader **1602** as electrical energy pulses or information bits and are communicated, in the sequence dictated by the particular program, to the command registers **1610**, **1612**, **1614**, respectively, communicating with the Y axis, or stock positioning component, the X axis or tool positioning component, and the *a* axis or bending component of the machine tool **100**. Information bits are also communicated from the tape reader **1602** to a miscellaneous function register **1617** and to a part identification control register **1618** which includes a counter **1619**. Still in digital form information bits from the respective command registers **1610**, **1612**, **1614** are communicated to an adder/subtractor or computer **1620** from which the signals are relayed to the digital-analogue converters **1622**, **1624**, and **1626**, respectively, for the X, Y, *a* axis components as controlled by the operation programmer or main program counter **1628** which cycles through a main program sequence including, in the present embodiment, a twelve step program. When the start button **1629** is depressed, the operation programmer **1628** accepts signals from the tape reader **1602**, communicates signals into the command registers **1610**, **1612**, and **1614** in response to or in conjunction with signals in the miscellaneous function register **1616**. The programmer **1628** responds to feedback or move-completion signals from the several components of the apparatus so as to control the sequences of motion. The computer **1620** includes a control circuit combination permitting simultaneous positioning movement of the three control axes Y, X, and *a*. From the converters **1622**, **1624**, and **1626** command signals received therein in digital form from the computer **1620** are communicated in analogue form to the control circuits **1630**, **1632**, and **1634**, respectively, commanding the movement of the Y, the X, and the *a* axes which control circuits are more fully described and shown in FIGS. **32**, **33** and **34** herein. A move-edit switch **1635** provides for movement of the several machine components or alternatively for cycling the control unit without physical movement of the machine components.

The numerical control unit **1600** includes also a command position display or readout **1640** which is connected selectively with one of the command registers **1610**, **1612**, **1614** by operation of the selector switch **1642** which is mechanically connected with a selector switch **1643** operative to connect the actual position display or readout **1644** with the one of the axis translators **1650**, **1652**, **1654** communicating respectively with the Y, X, or *a* component. A command position dial input **1660** comprising axis selector switch **1662** operative to control the position of switches **1642**, **1643**, the position-direction selector switch **1664**, the position coordinate number selector switches **1666**—**1674**, and the bend offset selector switch **1676** is connected to the command registers **1610**, **1612**, **1614** through a mode selector switch **1678** providing alternatively for communicating command signals into the command registers **1610**, **1612**, **1614**, and the miscellaneous function register **1616** from the tape reader **1602** or from manually input commands applied at the dial input **1660**. A sequence of signals may be displayed as a numerical coordinate including direction and axis selected in the display **1640**.

The unit **1600** also includes a plurality of regulated voltage power supply means furnishing independent voltage levels, respectively, the digital power supply **1680**, the operational power supply **1682** and the solenoid drive power supply **1684**. Start and stop controls **1629** and **1683** respectively provide, in addition to conventional main supply power on and off control (not shown) for starting and for stopping the blade making program or other operation of the control unit **1600**. A lamp **1687** represents a plurality of safety and/or program function indicator lamps which may be desired.

A program for a particular blade which is carried on tape **1606** will normally include an order quantity to be made, signals for which quantity are communicated to the miscellaneous function register **1616**. A blade quantity multiplier switch **1685** and a multiplier counter **1686** are also in communication with the miscellaneous function register **1616** and with an operation programmer **1628** which functions to sequence command signals in response to feedback, null, or completion signals received from the axis translators by the computer **1620** and communicated to the computer **1620** form the registers. The control register **1618** also receives a designation of the type of blade for which the program calls from the tape reader **1602**. This designation is displayed in a three-digit display **1689**. The counter **1619** is connected with a blade quantity display **1690** which includes four digit display positions, the first of which displays a quantity multiplier preset by the multiplier switch **1685** and the remaining three digit positions which display the quantity required of the blade called for by the particular program being operated.

The program contained in the tape **1606** for making a particular blade will include a plurality of command signals, one set for each shaping operation including one set for each successive bend. Blade making stock may require compensation for spring back due to the variations from one length or lot of stock to another. A plurality of bend offset dial switches **1692** provide means for compensating the program-commanded angle of bend for each successive bend in a particular blade. The bend offset selector dial switches **1692** communicate with a bend offset control or tool offset memory **1694** in which the amount of compensation for each successive bend, manually inserted to the switches **1692**, is stored and communicated to the digital-analogue converter **1626**. Manual insertion of minor correction to a program affecting one or more of the other axes of control may be provided for by addition of circuit components like the register **1694** and the dial switches **1692** to the respective converters **1622**, **1624**, and **1626**.

POSITIONING SERVO DRIVE MEANS

A feature of the present invention is the control of positioning movement of the X, Y and *a* components of the machine tool. In the present embodiment the means for positioning include means for controlling the rate of movement of the positioning means, and particularly of the rate of acceleration or deceleration of the positioning means being traversed to a selected predetermined position.

As is shown schematically in FIG. **32**, means for controlling the movement of the carriage **450**, and particularly the rate of movement thereof, includes the previously referred to circuit **1630** which controls the operation of a hydraulic motor **700** in response to signals from the control unit **1600**. The circuit **1630** comprises signal amplifiers **1708** and **1710** which are made alternatively responsive to the positive or negative sign of the received signal by operation of the error polarity switch **1712**. A signal in the form of voltage proportional to the digital counts received by the converter **1622** from the comparator or computer **1620** is impressed on the circuit **1630**. The signal, amplified in voltage by the amplifiers **1708** and

1710, is applied to an amplifier 1714 having a compensating network including a Zener diode and thence to an integrator loop 1718 which includes a gain control 1720 and a dual gain amplifier circuit having the amplifiers 1721, 1723 and 1725, the dual gain being afforded by compensation network including a Zener diode which becomes conductive at a signal voltage proportional to a displacement of the carriage of about 0.15 inch from a commanded position. The increased gain applied to the signal received by the integrator loop 1718 during carriage movement in the interval between 0.15 inch displacement and null, or between an actual position and the commanded position, provides increased sensitivity in the control circuit and a more positive null as the carriage is driven to the commanded position. The circuit gain from amplifier 1714 through the amplifier 1734 operates at saturation with error signals proportional to 1.0 inch from the command position and as much as 2.0 inches displacement at saturation can be utilized. Between 1.0 and 0.15 the compensation network of the circuit will provide a lesser gain. Output of the integrator loop 1718 is prevented, in the absence of a command signal from the control unit 1600, by the switch 1719 which connects the terminal of the loop 1718 to zero.

The circuit 1630 operates to control the hydraulic motor 700 of the servo drive 175 which, as previously discussed herein, is coupled to the lead screw 710 for imparting positioning movement to the carriage 450 toward and away from the X axis. The control or servo valve 1722 regulates fluid flow to and from the hydraulic motor 700 in proportion to the current in the valve operating coil 1730, which current is controlled by the coil driver 1732 in proportion to the voltage impressed thereon by the amplifier 1734. Voltage applied to the coil driver 1732 and coil 1730 is so modulated that an electrical null is reached and the valve 1722 moved into zero flow condition at the commanded position, stalling the hydraulic motor with a locked in column of fluid substantially at the maximum available pressure at both inlet and outlet, when the commanded position is reached.

Mechanically connected to the motor 700 is a tachometer generator 1736 capable of producing a voltage proportional to the speed of rotation of the motor and thus also proportional to the rate of movement of the carriage 450, the polarity of the tachometer voltage being opposed the voltage of the signal impressed on the amplifier 1734, thus affording decelerating control of the motor 700 as a null is approached.

Also coupled mechanically to the motor 700 sensing means or a transducer which here is an encoder 1740 which emits a signal representative of the position or the displacement of the carriage 450 with respect to a referenced position. The encoder 1740 of the present embodiment is capable of emitting signals, each of which is uniquely representative of a single position of the carriage 450. Signals from the encoder are conveyed by a multiconductor cable 1742 to the axis translator 1650 and thence to the computer 1620 in which the difference between the commanded and the actual positions operates to produce the voltage signal applied to the amplifier 1708.

The command signal is an analogue of a displacement error representing the algebraic difference between the position command, held in the register 1610 as applied thereto from the program tape 1606 or by means of the dial inputs 1660, and the actual position at any instant of the carriage 450.

Control of the acceleration of the motor is accomplished by resistance-capacitance input circuits in the amplifier or integrator loop 1718 such as to increase the time shape of the response curve and interval during which the servo valve is being opened in response to a command signal.

As will be evident to persons skilled in the art, the circuit 1630 includes two servocontrol loops. The rate control loop provides a feedback from the tachometer 1736 by which the signal input to the amplifier 1734 is modified. The position control loop affords a feedback from the position transducer or encoder 1740 to the computer 1620 of the control unit 1600 to modify the input thereto and thus the analogue signal communicated therefrom to the amplifiers 1708 and 1710.

As may be seen in FIG. 33, the control circuit 1632 is, in all material respects, like the circuit 1630 just described (reference numbers for like parts are identical) and is operative to drive the hydraulic motor 1300 of the positioning drive means 180. As has been described, the motor 1300, by its rotation of the lead screw 1312, positions the carrier 810 and the bending device 820 with respect to the Z and Y axes in response to command signals from the unit 1600.

As shown by FIG. 34, the circuit 1634, is likewise in all significant respects, like the circuits 1630 and 1632, the same reference numbers indicating like elements in the respective figures. As described hereinbefore, the motor 1530 of the servo drive 180 is operative to rotate the bending fingers of the device 820 about its axis 1414, and simultaneously, the rotatable punch and die sets represented by the set 871.

The servo drive means 175, 180, and 185 are available commercially from the Datex Division, Conrac Corporation, previously identified herein, as the "Pegasus Electrohydraulic Servo Drive" and include the Pegasus Model 130A servo valve, the Hartman HT-10 hydraulic motor, the Datex 13-506-B-A3 Encoder, and the Servo Tek SA-74OB-1 tachometer. In the apparatus 100 being described the servo drives have the capability of moving the carriage 450 and the carrier 810 at 1500 inches per minute or more, with very satisfactory repeatability of positioning.

A particular advantage achieved by the present invention is the reduction to a substantially constant minimum the time required for position feedback to the control unit 1600 from the encoder 1740. It will be evident from the foregoing description that very small increments of time loss in each movement of the carriage or of the carrier will result in an appreciable increase in the time required to complete a typical blade. The position sensing means operatively connected to the drive means for positioning the carriage 450, the carrier 810 and the bending device 820, comprises the position transducers or encoders 1740 which are capable of emitting a signal in the form of a coded array of pulses unique to any single position of the connected drive means. The time required to communicate the actual position signal to the NC unit is therefore a minimum and substantially constant, rather than variable and increasing with the displacement of the positioning means from some zero position. Moreover, it is not required that the encoder be rezeroed after a normal shutdown of the apparatus.

FINGER AND JAW CONTROL SYSTEM

According to the invention, the hereinbefore described bending device 820 includes a pair of stock engaging fingers 1410, 1412 alternatively extendible from and retractable into said device and driving means connected to said fingers operable to extend one and retract the other of the fingers. The mechanical train portion of the driving means has been described. According to a further aspect of the invention, the extension and retraction of the fingers is responsive to command signals from the means 1600 for storing and communicating such signals. In the apparatus 100 being described, and as shown in FIG. 35, means 190 for controlling the extension and retraction of the bender fingers 1410, 1412 comprises an electrohydraulic servo drive including a hydraulic motor 1802, a modulating servo valve 1804 and a tachometer 1806. Output of the hydraulic motor 1802 is connected, as previously described, to the finger position gear train by the splined shaft 1544, output of the motor 1802 is also connected to a reduction gear set 442, the output of which is communicated to an elevator cam 408 by the floating drive shaft 430. As has been indicated heretofore, the first jaw means 280 includes a stock thickness adjustment means comprising a thickness adjusting knob 372 adapted for manual adjustment, as previously described, and which is mechanically connected to the variable shaft 386 carrying the variable position center taps 1808 of a multiple ganged potentiometer 384 each resistor of which is provided with a trim potentiometer or

trimming resistor **1811**. The thickness setting of the knob **372** corresponds to a particular setting of the potentiometer **384** and the voltage at one or the other of the variable taps **1808**, thereof.

The elevator or thickness cam adjustment **400**, as previously described herein, provides means for adjusting the elevation of the Y axis component in accordance with the thickness of the strip material to be bent and as dictated by whether a particular bend will be made upward or downward. The cam **408**, as well as the fingers **1410**, **1412**, are mechanically connected to the variable tap **1812** of a second potentiometer **1814**, the terminals **1816**, **1818** of which are common with the terminals of the ganged potentiometer **384**. A positive voltage (+V) is connected to one terminal **1816** while a negative voltage (−V) is connected at the other terminal **1818**. The voltages +V, −V, positive and negative, are communicated to the potentiometer terminals from the operational amplifier power supply **1682** which is part of the control unit **1600**. The variable tap **1812** of the potentiometer **1814** is mechanically linked to the fingers **1410**, **1412** and to the elevator or thickness cam **408** such that the position of the cam, and of the first jaw means **280** previously described, is a function of the displacement of the variable tap **1812** with respect to its null position. From the variable tap **1812** of the potentiometer **1814** a voltage is communicated to one input **1819** of an operation amplifier network **1820** which voltage is representative of the position at any instant of the thickness cam **408** and of the fingers **1410**, **1412**. Shunts **1821** are provided at about two-thirds of the travel or voltage length of the potentiometer **1814** to enhance the precision of the outer portions of the variable tap **1812** travel, while providing for control throughout the travel range therebetween. The centers of potentiometers **384** and **1814** are connected at zero potential by the connector **1813**.

Upon receiving a command signal from the numerical control unit **1600** commanding an upward bend, the relay **1822** closes the switch **1824** to apply to the other terminal **1826** of the operational amplifier network **1820** a voltage representative of the elevation to which first jaw means **280** (and the upper surface of the free end of the strip held therein) should be brought and to which the finger strip surface **1424** of the finger **1412** should be brought, to initiate the desired upward bend in the free end of the strip being processed. The output **1828** of the operational amplifier **1820** is fed to an input **1830** of a second amplifier **1832**, the output **1834** of which is applied to the servo valve coil driver **1836** which is operatively connected to the hydraulic servocontrol valve **1804** through which fluid flows to the motor **1802** to drive the splined shaft **1544** to extend one of the bending fingers **1410**, **1412**. The electrohydraulic drive **190** includes the generator or tachometer **1806**, the output of which is a voltage proportional to the revolutions per minute of the motor **1802**. This voltage is communicated to the input **1840** of the amplifier **1832**, the output **1834** of which is thereby caused to decay as the tachometer voltage is increased so as to maintain control of the rotational speed of the hydraulic drive in a manner analogous to that of the rate control loop of the circuit **1630** previously described. As the finger **1412** is moved the elevator or thickness cam **408** is rotated by the drive described, the center tap **1812** of the potentiometer **1814** is displaced to alter the voltage which is applied at the input **1819** of the amplifier **1820**. As this voltage approaches the voltage received at the other terminal **1826** from the potentiometer **1810** the amplifier output **1828** decays such that the driving voltage received at the servo valve driver **1836** is reduced smoothly and rapidly to zero as the bender finger **1412** and the cam **408** arrive at their null positions responsive to the command signal received from the numerical control unit **1600**, as modified by the thickness knob setting.

On receipt of a command signal from the numerical control unit **1600** dictating a bend downward in the free end of the strip free end processed, the sequence of operation in the circuit described is substantially similar except that the relay **1842** causes the switch **1844** to close, applying a voltage opposite in sign, to that applied for an up-bend, to the input terminal **1826** of the differential amplifier **1820** and the voltage received by the servo valve driver **1836** from the amplifier **1832** is opposite in sign thereby causing rotation of the hydraulic motor **1802** and of the connected tachometer **1806** in the opposite sense. The bend-downward finger **1410** is extended while the bend-upward finger **1412** is correspondingly retracted. Simultaneously the cam **408** is moved to a position suitable for a downward bend responsive to the command signal, and to the stock thickness setting of the dial **374**.

As persons skilled in arts related hereto will now perceive, the action of the elevator means, particularly the cam assembly and control means **400**, serves to adjust or position the jaw means **280**, and particularly the cylinder axes **397**, **399** into collinear alignment with the rotation axis **1414**. The axis **395** of the lower jaw **300** is adjusted into collinear alignment where the end of the strip is to be bent downwardly; and the axis **397** of the upper jaw **302** is adjusted into collinear alignment with the axis **1414** when the end of the strip is to be bent upwardly. The arrangement provides that the angle to which the strip end is bent can be repeated with great accuracy and that equal increments of angle through which the head **1400** and finger **1410** or **1412** are rotated are directly proportional to equal increments of rotation of the drive **190** over the entire range of bend angle upward or downward.

OPERATION

It will have become apparent from the foregoing that the apparatus is capable of producing tire mold blades and the like continuously and automatically, the blades being successively alike, or different, in shape and dimensions. In normal operation the tape reader **1602** will read out from the tape **1606** a predetermined series, or sequence, of command signals necessary to command the predetermined feeding, clamping, punching, bending, and shearing operations required to alter the shape of the free-end E of blade-making stock S to form a complete tire mold blade. The tape reader **1602** is a high-speed readout using standard 1 inch wide 8 channel tape with flexowriter character set. The tape reader may also provide a part number or like identification of the part to which the particular program on the tape applies and may also include the desired quantity of this part, so establishing the number of automatic repetitions of a particular blade configuration.

The apparatus is connected to supply mains (not shown) for the supply of electrical energy and other utilities in the conventional manner.

Stock or material supply means in the form of a reel **252**, FIG. **2**, may contain blade-making stock up to 3 inches in width and from 0.010 to 0.080 inch in thickness. The stock may be of materials such as brass or one-quarter hard stainless steel.

The apparatus provides three modes of tape operation: a first mode, called "Dial," provides for operation of the machine cycles by input of commands to the registers **1610**, **1612**, and **1614** by manipulation of the dial inputs **1660**. The apparatus can be cycled step by step, with or without actual physical movement of the carriage or carrier by closure of valve **172**. The second mode, referred to as "Tape Step" provides that the tape be read by the tape reader one block at a time during which the apparatus performs the commanded operations from the particular block selected and the system completes that particular sequence of commands, whereupon the system goes to "complete" with the particular sequence of commands satisfied. In the Tape Step mode manual intervention, by pushing the start button, is required to move to the next block of commands on the tape. This Tape mode is of particular use for troubleshooting and for evaluating a tape the first time it is put on the machine and is used therefore to allow the operator to observe the apparatus operation and to determine whether any faults or miscommands have been put into the tape.

In the third mode, referred to as "Tape Auto" the machine performs in the same manner as in the Tape Step mode but proceeds automatically to the succeeding block of information or sequence of commands when the next preceding block of command signals is satisfied. Selection of one or an other mode of operation is made by the selector switch **1678**.

The tape can be edited or reviewed, in the present apparatus, without having any movements signalled to the drive means of the apparatus by placing the mode selector switch **1678** in the tape step position and the move-edit switch in its edit position. Upon pushing the start push button a first block of information will be read from the tape and the command position for the axis selected by the switch **1662** will be observed in the command position display **1640**. Rotation of the axis selector thumb wheel switch **1662** to one of the X, Y and *a* components will cause the command display selector switch **1642** and the actual position display selector switch **1643** to make contact with the appropriate command register **1610**, **1612** or **1614** and the command display will show a numerical coordinate corresponding to the position commanded. The blade-type N display **1689** and quantity Q display **1690** will change if the selected block of information contains updated signals. The miscellaneous function, M commands, will likewise be read and communicated to the register **1616**. The immediately succeeding block of information on the tape may then be reviewed by again pushing the start button **1681**. This particular portion of the system provides for review of the tape or portion of the tape programmed for the production of a particular blade-type, and is particularly advantageous in troubleshooting.

The apparatus is further provided with a blade quantity multiplier switch **1685** on the panel of the control console (not shown) and allows the operator the capability of selecting a multiple of the quantity of blades called for on the tape. For example, if a particular blade-type described by the tape included a program quantity of **50**, the blade quantity or Q display would show the number **050**, which number would be reduced by **1** upon completion of each single blade and one pass of the tape through the reader until the number displayed would be 000. **With the multiplier switch set at, for example**, 5, then the program would be repeated five times, resulting in a total production of 250 blades. With the blade quantity multiplier switch **1685** set at only one lot quantity of blades as called for on the tape would be made, whereupon the apparatus would proceed to the next type of blade called for by the tape program. This feature has the advantage of increasing the utilization of particular taped programs without requiring a complete reproduction of the tape itself.

Having ascertained the operation of the machine and the correctness of the tape by the procedure outlined, a free-end E of the blade material S is introduced into the Y axis component of the apparatus, care being taken to see that the stock is free from kinks and blemishes of a sort to prevent free passage into the apparatus. Both the first **280** and second jaw **460** means are opened. The first jaw means or bend jaws **280** normally have only a few thousandths of an inch clearance over the stock thickness. The setting of the stock thickness will be provided by manipulating the stock thickness gage hand knob **372**. The clamp **644** is moved free, the upper frame portion **566** of the stock straightener **550** is swung open and the movable guide rollers **494** moved away from the fixed guide rollers **490** to a width greater than the stock width being inserted. With the free end suitably positioned through both sets of jaws **280**, **460**, the stock straightener assembly **550** is closed and the guide rollers **494** adjusted suitably. The straightening rollers **564** are adjusted toward or away from the rollers **563** so that the strip material S will be suitably straightened as the straightening device **550** is moved along the strip.

With the free end of the blade stock material suitably positioned, the first jaw means **280** are closed to engage the stock and hold it securely against movement longitudinally of itself. The second jaw means, or stock feed clamp **460**, is opened and the carriage **450** is moved away from the first jaw means **280** so as to move the stock straightener **550** over the stock. Upon completion of the stock straightening movement, the second jaw means **460** are closed to engage the stock securely and the first jaw means **280** are opened. The stock carriage **450** now holding the stock is moved forward introducing the free end into the passage **852** in the punch and die slide carrier **810**, and particularly into the cutoff station **860**. With the carriage movement stopped, in response to a command signal, the ram **136** is actuated causing the stock to be sheared and establishing an 0 position reference on the stock.

To illustrate the operation of the apparatus according to the invention, the description turns now to FIGS. **21** and **36**. FIG. **36** is a sequenced diagram representative of operations of the apparatus in successive stages beginning at stage **1** at the lower left in FIG. **36**. In this first stage, a free-end E of the strip of blade material is supported cantileverly, as has been described. The outline at stage **1** shows a previous blade having been cut off. The jaw means **280** is actuated to grip the free end and the jaw assembly **460** is opened. The carriage **450** is then moved away from the jaw assembly **280** moving the straightening device **550** along the strip and repositioning the jaw assembly **460** with respect to the strip portion passing therethrough. The jaws **460** are then actuated to grip the intermediate portion of the strip material and the carriage **450** is advanced to the position shown at stage **2** while simultaneously the carrier **810** is traversed to position station A in juxtaposition with the free-end E at stage **2**.

Movements of the carriage **450** and the carrier **810** are accomplished substantially simultaneously and at rapid rates of travel. The traversing speed of either or both of the means for position according to the present invention may approach 2,000 inches per minute and a blade of the type being described can be completed in approximately 7 seconds.

With station A in coincidence with the end of the strip at stage **2** the ram **136** is actuated and returned.

The carriage **450** and the free-end E are advanced to the position shown in stage **3**, while simultaneously the carrier **810** is traversed to bring station C over the strip, the ram **136** is again actuated and returned, producing the hole **114**. At stage **4** the free-end E is again advanced and the carrier **810** moved to position station B in suitable juxtaposition to the strip to produce the hole **116**. At stage **5** the free-end E is again advanced, movement of the carrier not being required and a second hole **116** is punched by the action of the punch and die set at station B.

In stage **6** the free-end E is again advanced by movement of the carriage **450** and the punch at station C is traversed into suitable location and actuated to produce a second hole **114**. At stage **7** the carriage **450** is moved back while the carrier **810** is traversed to bring the punch and die of station F into suitable relation with the free-end of the strip to produce a portion of the notch **121**. The free-end is held in position and the carrier **810** is again traversed to bring the punch and die of station I into suitable position to form the radii and thus complete the notch **121**, as is shown. It will be apparent that the notch may have any width desired by causing the punch used to be actuated two or more strokes while moving the carriage holding the free-end E a suitable distance in the interval between strokes of the punch.

At stage **8** the free end is again advanced and the operation of stage **7** repeated. At stage **9** a third notch **121** is produced in this representative blade in like manner.

At stage **10** the free end is traversed back while simultaneously the carrier **810** is traversed to bring the punch at station L into operative juxtaposition with the free end. It will be recalled that the punches at stations L and M are equipped in the present embodiment to be rotated about axes perpendicular to the plane containing the X and Y axes, all as has been described in connection with the punch and die sets **871** and **872**. The punch is the station L is rotated by the operation of the drive means **185** of the *a* axis so as to produce the angled cut seen at stage **10** of FIG. **36**.

At stage 11 the free end is again advanced while the carrier 810 is traversed and while the punch and die set at station L are rotated so as to bring the punch and die set L into suitable relation with the strip to produce the angular notch shown at stage 11.

It will be appreciated that suitable means such as limit switches are provided to insure that punches are fully retracted prior to movement either of the carrier or of the carriage.

At stage 12 the free end will be advanced and retracted a plurality of times and the carrier traversed to bring the punch shown at station D into working relation to trim the blade to remove the material shown in phantom outline in stage 12.

In stage 13 the free end is retracted to the position shown whereupon the first jaw means 280 is actuated to grip the free end in the manner shown at stage 13. The bending device 820, which is traversed along the X axis by the traversing drive means 180, is brought into operating juxtaposition with the end E and the finger 1412 is extended while simultaneously the jaw means 280 is moved to bring the cylinder axis 397 of the nose portion into collinear alignment with axis 1414 of the bender head in the manner previously described herein. Rotation then of the finger 1412 in engagement with the cantileverly supported free end of the blade bends the end as shown at stage 13 to form a first and upward bend in the blade.

The bending device 820 is moved to clear the bent end of the blade and the jaw means 280 are caused to open and the jaw means 460 again advance placing the strip at stage 14 whereupon the jaw means 280 are again closed, the bending device is traversed into position and the finger 1410 is now extended. The jaw means 280 is again adjusted in elevation to place the cylinder axis 395 of the lower jaw 300 in collinear alignment with the rotation axis 1414 of the bending head. Again, the drive means 185 is actuated to rotate the finger of the bending device and to bend the cantileverly supported free end of the blade downward to form the bend shown at stage 14. The jaw means 280 are thereupon again opened and the second jaw means 460 again advanced to position the blade at stage 15 whereupon the jaw means 280 are again closed and again adjusted to bring the cylinder axis 397 again into coincidence with the axis 1414 of the bending device 820. Again the finger 1412 is extended into engagement with the lower surface of the free end and the bending head is rotated to form the bend seen in stage 15, whereupon the jaw means 280 is again opened and the strip again advanced through stages 16 and 17 forming an additional downward bend and additional upward bend in the same manner as has been described, whereupon the jaw means 280 are again opened and the now completed blade is advanced to the position shown in stage 18 and the bending device and carrier 810 are again traversed to bring the cutoff of the station A, which in the present embodiment is the cutoff device 860 previously described, into operative relation with the free end of the strip and actuated by the ram means 136. The now completed blade severed from the strip is dropped through the opening in the press platen to a suitable receptacle and the cycle is ready to be repeated. After each single blade is produced, the quantity displayed is reduced by 1 and the section of tape 1606 is repeated until 0 parts are left to be made, the multiplication factor is then reduced by 1 and the cycle is repeated until the total preset quantity is reduced to 0, whereupon the tape containing the program goes automatically to the next type of part. In the sequence for making a blade, the free end of stock carried in the carriage 450 of the Y axis component is moved to position the free end E at a predetermined position in response to a command signal from the control unit 1600. Also in response to a command signal from the control unit the carrier 810 is moved into a position which places a preselected punch and die set into a predetermined position with respect to the free end of the stock. Both the carriage and the carrier are driven to their respective predetermined positions very rapidly and are positively decelerated, as has been described hereinabove, to a 0 or null position corresponding to the coordinates dictated by dial input 1660 or by the information in the numerical control tape 1606. When actual position and command position coincide, an electrical null is communicated to the programmer 1688 and the actuating means, in particular the ram 136, is actuated to stroke the punch through the material into its mating die button. Conventional safety switches may be used to prevent the ram from cycling except when the proper position is assured. The ram having completed its cycle, down and up, and the punch of the punch and die set likewise having returned to its up, or home, position, the cycle is repeated to achieve the desired number of notches, holes, and the like, required by the program. Repeated strokes may be made so as to nibble material from the free end of the stock.

The apparatus provides further for manual input of an amount of overbend to compensate for springback. The desired overbend addition to the programmed command signals from the tape and applied in the plurality of bend-offset switches 1692 which may be preset by the operator. In response to command signals received from the tape reader, the drive means 175 moves the bending device into suitable position while the bend finger and jaw actuating means 190 extend the bending finger appropriate to the desired direction of bend and the elevator means 400 positions the first jaw means 280 so that the center of the desired bend radius normally will coincide with the rotation axis of the bending device. For larger radii, when the finger has been extended to the predetermined position determined by the command signal as modified by the thickness setting and the first jaw means have been elevated to the appropriate position, an electrical null is communicated to the control circuit 1600 whereupon the bending device rotation drive 185 is actuated in response to a command signal to rotate the finger in the appropriate direction and amount to bend a portion of the free end of the stock. As the actual bend angle position approaches the command position an electrical null is communicated to the control circuit 1600, whereupon the bending device rotational motion is reversed and the bender head is rotated back to its 0 or home position. The bending jaws are opened and the stock free end is moved forward into the preselected position for the next successive bend to be made and the steps are repeated to produce a second bend.

When the particular blade has been completely shaped by punching and by bending, the free end is again fed forward in response to a command signal and the carrier is traversed to position the cutoff station over the stock, the completed blade extending beyond the cutoff line, as before, when the null positions are signalled, indicating that both carriage and carrier are in the commanded position, the ram is actuated to move the cutoff knife and the finished blade is cut off and dropped into the delivery chute. If desired, the cutoff knife may again be actuated to trim the succeeding free end. The cycle is then repeated automatically to produce the number of blades called for in the numerical control tape as modified by the input at the blade multiplier selector.

Following the cutoff of a completed blade, the first clamp jaw means are again moved to hold the stock; the second jaw means or stock-feed jaws are opened and the stock positioner carriage is again moved away from the first jaws, moving the straightener assembly over the stock extending from the reel. A short length of stock is tensioned and straightened and levelled as each blade is completed and before a succeeding blade is begun.

The tape spooler provides for the tape to be recycled for each blade so that a single program is repeatedly used until the desired quantity is attained, whereupon the tape is spooled forward to bring a program for a succeeding blade into operative relation with the tape reader.

While certain representative embodiments and details have been shown for the purpose of illustrating the invention, it will be apparent to those skilled in this art that various changes and modifications may be made therein without departing from the spirit or scope of the invention.

What we claim is:

1. An apparatus for making blades for use in tire molds comprising an automated machine tool including first means for positioning a cantilevered free end of an indefinite running length of strip selectively in each of two opposite directions along an axis parallel to said length in response to a command signal, second means for positioning a plurality of shaping tools successively individually in preselected differing sequences of proximate relationships with said free end in response to a series of command signals, third means for actuating each such tool while the same is in such proximate relationship to effect a change in shape in said free end in response to a command signal, and control means for storing and communicating to each said means a predetermined sequence of command signals.

2. Apparatus for making blades for use in tire molds comprising means for positioning a cantilevered free end of an indefinite running length of blade strip stock including stock gripping first jaw means having opposed surfaces engageable with said cantilevered end, a bending device movable between an inoperative remote position spaced from said jaw means and a working position proximate said jaw means, means for moving said device between said working and said remote position, said device having a stock engaging cantileverly supported finger engageable with the free end of said stock adjacent to and outwardly of said first jaw means and rotatable about a rotation axis substantially parallel to the strip engaging surfaces of said jaw means, and drive means connected to said device to effect rotation of said finger to a predetermined angle to bend a portion of said free end into angular relation with respect to another portion of said stock engaged within said jaw means.

3. Apparatus as claimed in claim 2 wherein said jaw means includes an upper and a lower bending nose portion each of particylindrical form and each disposed respectively about a cylinder axis parallel to said stock engaging surfaces, and further comprising means for selectively placing said rotation axis and each said cylinder axis respectively in collinear relation.

4. Apparatus as claimed in claim 1 wherein said first means for positioning comprises carriage means movable along a path parallel to said axis, guide means for guiding said carriage means along said path, and driving means connected to said carriage means for moving said carriage means successively to a predetermined plurality of positions in response to said sequence of command signals.

5. Apparatus as claimed in claim 1 wherein said plurality of shaping tools includes a plurality of material removing tools and at least one bending device.

6. Apparatus as claimed in claim 5 wherein said bending device includes a bending finger cantileverly extended from said device and engageable with said free end, and further including bending jaw means adapted to engage said strip, said third means including means for rotating said finger and said free end through a predetermined angle with respect to said jaw means.

7. Apparatus as claimed in claim 1 wherein said second means comprises track means defining a track transverse to the first said axis, carrier means supporting said plurality of shaping tools and movable along said track in predetermined fixed spaced relation with respect to one another, and drive means connected to said carrier means for moving said carrier means into said predetermined relation with said free end in response to said sequence of command signals.

8. Apparatus as claimed in claim 1 wherein at least one of said means for positioning comprises servo drive means including a feedback transducer capable of emitting a signal which is a function of the actual position of said means, and a feedback tachometer generator capable of emitting a signal which is a function of the rate of movement of said means.

9. Apparatus as claimed in claim 8 wherein said transducer is an encoder capable of emitting a signal which is uniquely representative of the said actual position.

10. Apparatus as claimed in claim 1 wherein said control means for storing and communicating signals comprises a memory device for storing a predetermined sequence of command signals, and including drive means connected respectively to each of said first and second means for positioning to provide positioning movement thereof, a plurality of control circuits connecting said drive means respectively with said control means for selectively communicating said command signals to said drive means.

11. Apparatus as claimed in claim 1 wherein said means for storing and communicating signals comprises a memory device for storing a predetermined sequence of command signals, a plurality of servo control circuits each communicating with a respective one of said means for positioning and with said memory device, and including drive means respectively connected to each of said first and second means to provide positioning movement thereof, and a transducer connected respectively to each of said drive means to provide signals to said circuits responsive to the respective positions of said means for positioning.

12. Apparatus as claimed in claim 1 wherein said second means comprises means for positioning a bending device including a bending finger to place said finger in engagement with one of the top and bottom surfaces of said strip, and said third means includes means for rotating said finger about an axis transverse to the first said axis in response to said sequence of signals, whereby a portion of said free end will be displaced angularly with respect to a next adjacent portion thereof by said finger.

13. Apparatus as claimed in claim 1 said second means further comprising a plurality of punch and die sets including a set adapted to remove material from said strip, at least one set adapted for rotation about an axis generally normal to the plane defined by the first said axis and the direction of movement of said second means, and a set comprising cutoff means for severing said free end from said strip.

14. Apparatus as claimed in claim 13 further including a plurality of springs respectively operative to urge the die portion of each of said punch and die sets to an idle position elevated slightly with respect to its working position.

15. Apparatus as claimed in claim 1 said second means further comprising drive means including a lead screw, carrier means supporting said plurality of tools and connected to said screw, motor means connected to said screw, and means for controlling the driving movement of said motor means responsive to the displacement of said carrier from a predetermined position.

16. Apparatus as claimed in claim 1 wherein at least one of said plurality of shaping tools is rotatable about a rotation axis oriented transversely with respect to the first said axis in response to said signals.

17. Apparatus as claimed in claim 16 further comprising connecting means communicating rotational movement from one of said bending device and said rotatable one of said tools to the other thereof whereby said device and said one tool are in positive timed rotational relation with each other.

18. Apparatus as claimed in claim 5 further including a carrier supporting said plurality of tools and connected to said bending device in fixed space relation thereto, and track means supporting said carrier and said device for collinear movement transverse to the first said axis.

19. Apparatus as claimed in claim 1 said first means further comprising drive means including a lead screw, carriage means adapted to engage said strip and connected to said lead screw, motor means connected to said lead screw, and means for controlling driving movement of said motor responsive to the displacement of said carriage from a predetermined position.

20. Apparatus as claimed in claim 4 wherein said first means for positioning said free end further comprises first jaw means engageable with a portion of said strip, second jaw means engageable with said strip and mounted on said carriage means for movement therewith, a strip straightening device mounted

on said carriage means and adapted to receive an intermediate length of said strip therein, said driving means being adapted to move said second jaw means away from said first jaw means while said first jaw means engage said strip and while said second jaw means are disengaged from said stock strip, whereby said strip is straightened by movement of said device therealong and said second jaw means are repositioned with respect to said strip.

21. Apparatus as claimed in claim **20** including pivot means mounting said straightening device for limited pivotal movement with respect to said carriage.

22. Apparatus as claimed in claim **3** wherein said bending device includes a pair of stock engaging fingers alternatively extendable from and retractable into said device, a head rotatably mounted within said device having slide ways therein disposed at small equal and opposite angles with respect to said rotation axis receiving said fingers for movement along said ways, and finger drive means connected to said fingers and operable to extend one and retract the other of said fingers.

23. Apparatus as claimed in claim **22** further comprising means for storing and communicating command signals connected to each of said drive means and effective to control individually the driving movement thereof.

24. Apparatus as claimed in claim **3** including means for moving said finger toward and away from said rotation axis independently of the rotation of said device.

25. Apparatus as claimed in claim **3** including means for extending and retracting said finger with respect to said device independently of the rotation of said device.

26. Apparatus as claimed in claim **3** wherein said bending device includes a plurality of rotatable input shafts, a rotatable head mounted within said device and having slide ways therein, a pair of fingers including the first said finger each having a gear rack and being slidably received in said slide ways, a rack pinion mounted rotatably in said head and engaging at least one of the racks, said drive means including means connecting said head and one of said input shafts for positive rotational relation therebetween, a gear train connecting said pinion to an other of said input shafts and operative to prevent rotation of said pinion about its own axis during rotation of said one input shaft and to provide positive rotational relation between said rack pinion about its own axis and said other input shaft.

27. Apparatus as claimed in claim **26** wherein said gear train includes a planetary gear set having a first gear in geared engagement with said one shaft, a second gear in geared engagement with said other input shaft, and planet gears drivingly connected to said pinion and to said shafts.

28. Apparatus as claimed in claim **3** further comprising a base, track means fixedly mounted on said base, said bending device being supported for movement along said track means, said drive means including a shaft supported for rotation without axial movement on said base and slidably received in said bending device, and motor means carried by said base and drivingly connected to said shaft.

29. Apparatus as claimed in claim **3** further comprising means for adjusting the positions of said first jaw means with respect to said rotation axis, means for adjusting the spacing between said finger and said axis and means responsive to a command signal operative to actuate both said means for adjusting.

30. Apparatus as claimed in claim **29** the second said means for adjusting further comprising means for controlling the movement of said finger toward and away from said rotation axis and of said jaw means responsive to a preset thickness of said strip.

31. Apparatus for making blades for use in molds for tires comprising a base, a press having a ram reciprocable along a vertical axis mounted on said base, ram drive means for actuating said press in response to a command signal, first means mounted on said base for positioning a free end of an indefinite running length of blade making stock along a generally horizontal axis, said first means including horizontal rock shaft means mounted on said base, a bed member having guide means thereon lying generally parallel to said horizontal axis and mounted for pivotal movement about said rock shaft means, first stock gripping jaw means fixed to said member and spaced therealong from said rock shaft means, carriage means supported on said guide means for movement therealong and carrying stock gripping second jaw means, clamp drive means operative to clamp and to unclamp said first jaw means in response to a command signal, clamp drive means operative to clamp and to unclamp said second jaw means in response to command signals, an elevation control device interposed between said base and said bed member and spaced from said rock shaft means, adjusting drive means for adjusting the elevation of said first jaw means, carriage drive means connected to said carriage means for moving said carriage means along said guide means toward and away from said first jaw means and said vertical axis in response to command signals, second means for positioning a selected one of a plurality of shaping tools into predetermined proximate relation to said free end and to said press, said second means including tool guide means providing a horizontal track transverse to said vertical and said horizontal axis, carrier means carrying said plurality of tools and a bending device movable along said track, and carrier drive means connected to said carrier means and said device for moving said carrier and said device in response to a command signal, said bending device including a bender finger engageable with said free end, bend driving means connected to move said finger to bend said free end, and means for storing and communicating a predetermined sequence of command signals including a memory device and a plurality of control circuits connected respectively to each of said drive means to communicate said command signals thereto.

32. A method for making blades of successive diverse configurations for use in molds for molding tires comprising the steps of: gripping a portion of a running length of strip material to support cantileverly a free end of said strip, moving said free end while so supported stepwise selectively in each of two opposite directions along an axis parallel to said length to position said free end successively in a series of predetermined fixed locations, moving a plurality of shaping tools to position individual ones of said tools in a first predetermined sequence thereof into successive shape altering engagements between said free end and said sequence of said tools, cutting off from said free end a portion thereof so as to provide a second free end, moving said second free end stepwise selectively in each of two opposite directions along said axis to position said second free end successively in a second series of predetermined locations, moving said plurality of tools to position individual ones of said tools in a second predetermined sequence thereof at least one of said second series and said second sequence differing from said first series and said first sequence respectively and into successive shape altering engagements between said second free end and said second sequence of tools, each of said engagements being interposed immediately between two successive relative movements between said tools and said free ends, whereby a plurality of blades of diverse predetermined configurations are successively formed from a single running length of strip material.

33. The method claimed in claim **32** wherein at least one of said moving steps includes moving a first plurality of material removing tools successively individually individually into predetermined sequences of material moving engagements with each said free end, moving at least one bending tool into surface engagement with at least one said free end and bending a portion of such free end successively in each of two opposite directions to angled relationship with respect to an adjacent portion of such free end.

34. Apparatus as claimed in claim **11**, at least one of said plurality of servocontrol circuits including means for controlling the rate of movement of the respectively associated one of said means for positioning as such means approaches the commanded position thereof.

35. Apparatus as claimed in claim 34 further comprising servo valve means for regulating fluid flow to and from said drive means connected to a respective one of said means for positioning and responsive to the respectively associated servocontrol circuit to stall such drive means by applying a locked-in column of fluid at substantially the maximum available pressure at both inlet and outlet of such drive means when the commanded position is reached by said drive means.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,581,535 Dated June 1, 1971

Inventor(s) William L. Hinks and Harry L. Hosterman

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 65, should read "apparatus of FIG. 1" instead of "apparatus of FIG."
Column 5, line 38, "75" should read -- 175 --.
Column 6, line 33, "302" should read -- 301 --. **(1st occur.)**
Column 8, line 14, "297" should read -- 397 --.
Column 9, line 31, "undesirably" should read -- undesirable --.
Column 9, line 51, "582, cross-shafts 582, 583" should read -- The cross shafts 582, 583 --.
Column 9, line 75, "540" should read -- 650 --.
Column 11, line 65, "rotatably" should read -- rotatable --.
Column 12, line 24, "bushing 1072" should read -- bushing 1062 --.
Column 12, line 44, "1107" should read -- 1106 --.
Column 12, line 65, "assemblied" should read -- assemblies --.
Column 13, line 36, "132" should read -- 1232 --.
Column 14, line 5, "spaded" should read -- spaced --.
Column 15, line 38, "pinch" should read -- punch --.
Column 16, line 14, "the" first occurrence, should read -- and --.
Column 17, line 31, "1617" should read -- 1616 --.
Column 18, line 27, "form" should read -- from --.
Column 20, line 22, "13-506-B-A3" should read -- 13-506-3 --.
Column 21, line 74, "strip free end processed" should read -- strip being processed --.
Column 24, line 73, "is" first occurrence, should read -- in --.

Signed and sealed this 7th day of December 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Acting Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
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